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instruction manual

CVR-551/S-686

NORTH ATLANTIC
industries, inc.

complex voltage ratiometers

MODEL ~~CVR 551/VM-202~~

OPERATING AND INSTRUCTION MANUAL

COMPLEX VOLTAGE RATIOMETER

MODEL CVR-551 / S-686
~~VM-207~~

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

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COMPLEX VOLTAGE RATIOMETER

TABLE OF CONTENTS

PAGE

Introduction..... 1.1

General Description..... 2.1

Specifications..... 3.1

Illustration and Circuit Schematics..... 4.1

SECTION I - OPERATING INSTRUCTIONS CVR

Description of Terminals - Connectors..... 5.1

Description of Controls..... 6.1

Displays..... 7.1

Operation..... 8.1

Quadrature Channel Check and Calibration..... 8.1

General Phase Angle Voltmeter Measurements..... 9.1

To Measure In-Phase Ratio..... 9.1

To Measure Quadrature..... 9.2

To Measure Phase Angles..... 9.3

Functional Schematic.....10.1

SECTION II - PHASE ANGLE VOLTMETER

SECTION III - RATIO BOX

INTRODUCTION

Precise determination of the complex transformation ratio of transformers, resolvers, amplifiers, and a-c transducers is a fundamental measurement problem which has become increasingly important in recent years. Present-day a-c ratio measurements require accuracies which now approach parts per million.

Complex transformation ratio measurement consists of comparing the output of the device under test with the output of a precision ratio divider, both excited from the same source. When these two outputs are made equal by phase-sensitive nulling, the ratio box registers the in-phase transformation ratio of the test piece. The phase shift across the test piece is determined by measuring the residual quadrature voltage. This is measured by using a suitable voltmeter calibrated in degrees or radians or by injecting a calibrated quadrature voltage of proper polarity to achieve a complete null. Although this is a classic measurement, the orders of accuracy now required have led to an entirely new technology in which error sources only recently have been defined. It will be shown in this handbook how the high accuracy inherent to the precision ratio box can be realized in complex transformation ratio measurements by integrating the complete measurement circuit into a single instrument called a Complex Voltage Ratiometer.

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General Description

The Complex Voltage Ratiometer is a device which includes, in one package, all of the elements necessary to measure all of the components which define a particular AC voltage or current. This completely integrated instrument permits direct reading of phase angle, in-phase transformation ratio, and quadrature amplitude. All other related circuit parameters may be derived with a high degree of accuracy.

In-phase ratio measurements are made with a North Atlantic Model RB-504 Ratio Box and Model T-120 precision inversion transformer. This combination has a basic two part per million ratio accuracy while permitting the measurement of ratios of ±1.111110 by means of a polarity reversal switch.

Quadrature, as well as phase angle measurements, are performed by direct reading on the voltmeter. The phase angle measurements may be made in either radians or degrees. This selection can be obtained by a toggle switch on the front panel. All of the measurements described maintain specified accuracy although the nominal frequency varies over a bandwidth of ±5%.

An added feature, to facilitate any calibration of the passive networks that may be desired, is the internal 90° phase standard (also passive). This phase standard, in conjunction with the self-contained Phase Angle Voltmeter, permits any self-checking that may be desired with no additional equipment.

In addition to the circuitry and instrumentation for these basic measurements, a standard, calibrated Phase Angle Voltmeter and Ratio Box is contained within the instrument with provisions for their general use. (See Phase Angle Voltmeter and Ratio Box Sections.)

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SPECIFICATIONS

MODEL CVR-551 S436

RANGES:

In-Phase Ratio, R_I	.000000 to ± 1.111110
Phase Angle, (Note 1)	±(1.0 to 300) Milliradians F.S.
	±(0.1 to 30) Degrees F.S. in 6 calibrated ranges

ACCURACY:

In-Phase Ratio, R_I (Note 2)	$\pm\left[.0002 + \frac{.0002}{R} + 100\sigma \tan\alpha\right]\%$ of reading
Phase Angle Error (Note 3)	$\pm\left(\frac{.00002}{R} + .00003 + \sigma\sqrt{\tan^2\alpha + .03FS}\right)$ Radians
	$\pm\left(\frac{.0011}{R} + .0017 + 57\sigma\sqrt{\tan^2\alpha + .03FS}\right)$ Degrees

PHASE ANGLE VOLTMETER MODE (Note 4)

PAV ACCURACY

In-Phase Voltage, E_1	±3% F.S.
Quadrature Voltage, Eq	±3% F.S.

PAV RANGES

In-Phase Voltage, E_1	300 micro-volts to 300 volts in 13 calibrated ranges
Quadrature Voltage, Eq	300 micro-volts to 300 volts in 13 calibrated ranges

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GENERAL CHARACTERISTICS

Isolation Transformer:	100VA
Null Sensitivity Factor, n:	0.25%FS or less than 1.0 microvolt
Operating Frequency, f:	400~ ±5%
Input Excitation Level:	.35f to 300V RMS Max. 1.0 Volt Minimum
Input Power	115V, 50 to 400~ @75 watts
Dimensions:	19"W x 12 1/4"H x 14"D
Weight:	75 lbs. (approx.)

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NOTE 1: Range of α is limited at large signal levels by $\alpha < \sin^{-1} \frac{40 \text{ volts}}{Es}$

NOTE 2: δ = orthogonality error

δ = .0025 radians for excitation, Es of from 2.5 to 300 volts .001 radians over 5% Bandwidth

δ = .0025/Es, radians for excitation, Es of from 1.0 to 2.5 volts

NOTE 3: Does not include small angle approximation error for $\alpha \cong \text{Tan} \alpha$

NOTE 4: A more detailed specification of the instrument's performance in this mode may be obtained by referring to the voltmeter section (Section II) of the handbook.

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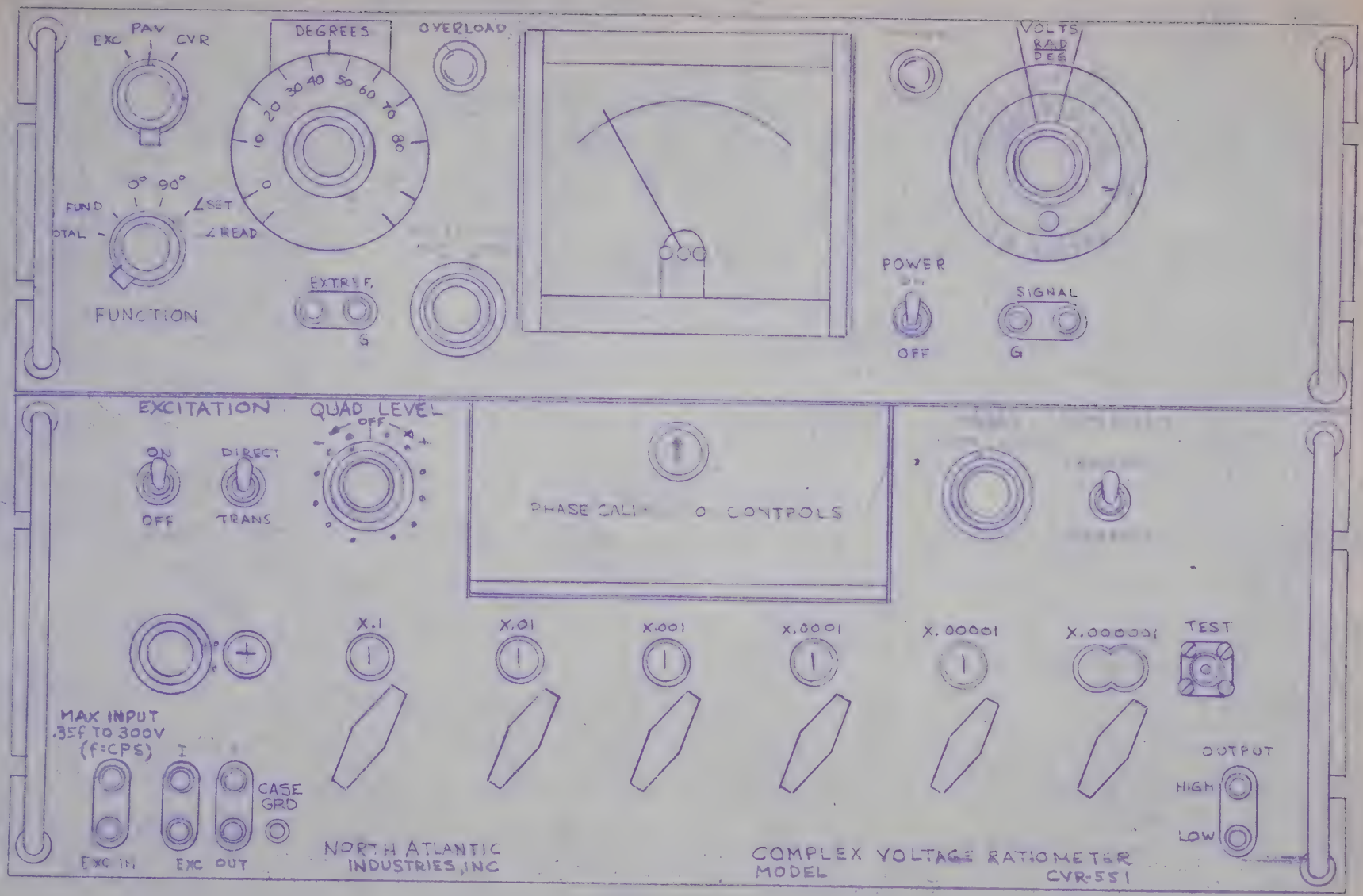
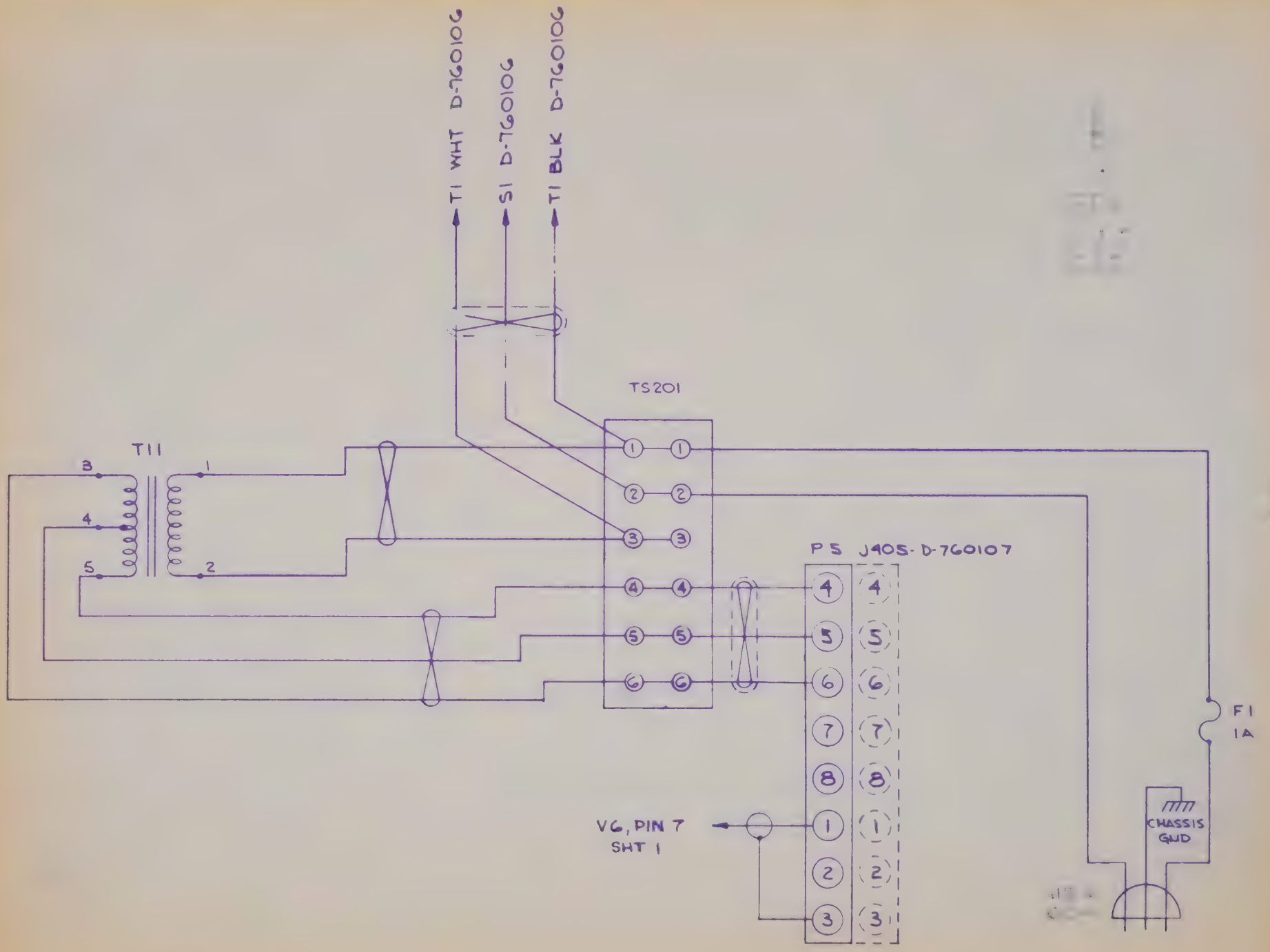


MODEL CVR-551 TERMINALS AND CONTROLS


T1 WHT D-760106
S1 D-760106
T1 BLK D-760106
TS201
T11
P5 J405-D-760107
F1
1A
CHASSIS GND
V6, PIN 7
SHT 1

SECTION I

OPERATING INSTRUCTIONS CVR

SECTION I

DESCRIPTION OF

TERMINALS AND CONNECTORS

EXC IN (FRONT PANEL)

Grayhill type 29-1 with hot connection made to red terminal. Ground or low connection is made to black terminal.

EXC OUT (FRONT PANEL)

These terminals are used to supply power to the test item. The connections are intended to be made by use of a 4 terminal I/E Network. The two terminals marked "I" (same type connector as EXC IN above) are wired directly to the test item. These wires will carry the current drawn by the particular unit being tested. Two wires are then connected between the input terminals at the test item and the "E" terminals (Grayhill similar to "I" terminals). In each case, the black in intended for the common or low potential point and red for the high voltage terminal. This connection permits the measurement of high current carrying devices (e.g., power transformers, etc.) while effectively eliminating any errors caused by line drop. If the load should be of a "light nature" (e.g., operational amplifier, etc.) shorting bars are available to connect the "I" terminals to the "E" terminals eliminating the need for dual wiring. "E" terminals become the input for the Ratio Box when Mode Switch is in the PAV position.

GROUND TERMINAL (FRONT PANEL)

This terminal is used to connect the "E" terminal low to chassis by means of a shorting link. This connection should be made at all times unless test conditions are such that source excitation low and case ground are connected externally. (ex., CVR is rack mounted and rack is connected to "EXC IN" low and "E" terminal low.

OUTPUT (FRONT PANEL)

Hi-Lo terminals are output of the Ratio Box in the PAV Mode.

TEST (FRONT PANEL)

Dage #3909-1 jack. This triaxial connector mates with the

test cable (NAI #782078). The connector is insulated from the panel.

TEST CABLE

NAI #782078 Test Cable Assembly provides a convenient means of clipping onto, or plugging into the output of the item under test. The red lead is the HI side and black is the LO side. The connector end mates with the test jack on the front panel.

SIG AND REF (FRONT PANEL)

Grayhill 29-1 types. These terminals are used only when the voltmeter is used for auxiliary measurement. This is the case where the EXC-PAV-CVR Switch is in the PAV position. (See PAV Section.)

EXC IN (REAR PANEL)

MS310A-14S-2P	These are optional features that perform the same functions as the front panel connector

EXC OUT (REAR PANEL)

MS3102A-14S-2S	These are optional features that perform the same functions as the front panel connector.

TEST (REAR PANEL)

Amphenol #165-83	These are optional features that perform the same functions as the front panel connectors.

SIG, REF, AND OUTPUT (REAR PANEL)

Amphenol UG-290/U	These are optional features that perform the same functions as the front panel connectors.

CAUTION: OBSERVE SPECIFIED MAXIMUM VOLTAGE RATINGS. HIGHER VOLTAGES WILL EFFECT ACCURACY OF SOME OF THE INDUCTIVE ELEMENTS CONTAINED IN THE INSTRUMENT.

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DESCRIPTION OF

CONTROLS

POWER ON-OFF

This toggle switch controls the power to the Phase Angle Voltmeter and amplifiers as indicated by the green pilot light.

EXCITATION ON-OFF

This toggle switch controls the excitation voltage supplied to the item under test. Thus, as specific tested items are changed, there is no danger (with switch in Off position) of physical hazard to operator due to EXC OUT terminals being excited.

EXCITATION DIRECT - TRANS.

This toggle switch applies the excitation voltage directly to the EXC OUT (I) terminal or through a power isolation transformer as desired. Test piece requirements will determine the mode.

EXC - PAV - CVR

This selector is used to determine the instrument's operating mode. In the EXC position, the excitation is applied to both the Reference and Signal Channels of the voltmeter so that complete evaluation may be made of the source. In the PAV position, the Phase Angle Voltmeter and the Ratio Box are useable and are independent of the other instrumentation contained in the Complex Voltage Ratiometer. In the CVR position, all circuitry and instrumentation is included for complete evaluation of AC voltages.

REFERENCE (ADJ-OPER)

This concentric switch/adjustment is used to set the voltmeter reference channel gain to accommodate the total excitation voltage level applied. The outer two position switch is set to the ADJ position which permits the inner adjustment to set the voltmeter reading to the red line indication. This is the proper level for optimum opera-

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tion of the Phase Angle Voltmeter. The actual setting is not critical, and any reading between 3 and 10 would normally permit satisfactory operation. The outer switch should be set to the OPER position for normal operation.

FUNCTION SELECTOR

This switch is used to select the desired function of operation for the instrument.

TOTAL, FUND, 0° and 90° positions can be used when the operating mode of the instrument is in any one of the three positions, EXC-PAV-CVR.

∠ SET and ∠ READ positions are applicable only when the instrument is in the CVR mode.

In the 0° and 90° positions, the Phase Angle Voltmeter is connected so as to read an in-phase or quadrature component of the signal applied. In the FUND position, the Phase Angle Voltmeter functions as a standard voltmeter with the addition of filters in both the Signal and Reference Channels. This results in a reading equivalent to the total vector voltage of the fundamental signal. In the TOTAL position, the filters are removed, and the instrument functions as a standard voltmeter reading the entire signal including harmonics.

The ∠ SET and ∠ READ positions are used after having obtained nulls in the 0° and 90° positions. In the ∠ SET position, the ratio box output voltage is removed from the null circuit, permitting the in-phase component of the test piece voltage to be read on the voltmeter. In the ∠ READ position, the quadrature amplifier output voltage is removed, permitting the quadrature component of the test piece voltage to be read.

ANGLE SCALE SET (HI-LO)

This switch selects the input level to the isolation amplifier. The HI position provides a 300 to 1 attenuation to large in-phase voltages which might saturate the amplifier. In the LO position, the attenuation is removed permitting the measurement of low level in-phase voltages. The inner knob provides a fine level control of the amplifier output.

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RADIANS-DEGREES

This switch converts the readings directly to either radians or degrees.

QUAD LEVEL

This concentric control permits a high resolution setting of the quadrature injection level. The outer knob provides coarse level control in six steps. The control position marked "OFF" completely removes the quadrature injection. Polarity is selected by setting to either the right (Plus) or left (Minus) of the "OFF" position. The inner knob provides fine level control by using a vernier potentiometer. This is a two in one potentiometer consisting of a main resistance element and a vernier element on the same shaft. Turning the shaft in either direction rotates the vernier slider until it reaches a mechanical stop. Further rotation causes the entire vernier element to slide on the main element. Therefore, a medium adjustment is available on either end of the vernier.

RATIO BOX POLARITY CONTROL

This control has two positions. It reverses the polarity of the voltage applied to the ratio box through the inversion transformer to permit full ratio ranges of either polarity. The extreme left window of the ratio read-out displays the particular polarity setting.

RANGE SWITCH

This switch selects the full scale voltage and/or angle being measured by the phase angle voltmeter. There are 13 positions ranging from 300 microvolts full scale to 300 volts full scale. The 300 microvolts full scale is made available to provide adequate null sensitivity when low excitation voltages are used. It may be noted when operating from a high excitation voltage that a meter deflection of less than 1 ppm of the excitation voltage level may be observed. The range switch is calibrated in voltage and angle with an adjustment capability between them. The voltage scale is in red and angle scale in black.

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DISPLAYS

METER

The meter is a zero center DC milliammeter calibrated to read the RMS value of a sine wave. For TOTAL or FUND reading, the needle deflects to the right. For 0°, 90°, ∠ SET and ∠ READ measurements, the meter deflection may be either left or right dependent upon the relative phase of the voltmeter input with respect to its reference.

CAUTION: BY ITS NATURE THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE CAN OCCUR IF THE SIGNALS ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

PHASE ANGLE DIAL

This dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter within the Phase Angle Voltmeter. It, in conjunction with the 0° and 90° selection, determines the total phase shift through the reference channel with respect to the signal channel. Care must be taken to prevent high impact with the stops at either end that may slip dial.

OVERLOAD LAMP

The lamp marked "OVERLOAD" lights when the signal exceeds five times full scale reading on the Phase Angle Voltmeter. This indication warns of impending signal amplifier overload and the attendant inaccuracies which will occur when large saturating signals are present. The actual amplifier overload occurs at approximately twice this setting (or about 10 times full scale signal).

FUSES

There are 3 fuse holders mounted on the rear of the instrument. A 1 amp fuse (on power cord bracket) is used for

Phase Angle Voltmeter and amplifier power. In addition, there are two fuses on the CVR rear panel. There is a one amp fuse (F2) protecting the ratio box output. Also, there is a 1 amp fuse (F1) protecting the excitation circuit. All fuses must be replaced with the identical type removed. If this is not done, the instrument's performance may be degraded.

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OPERATION

The instrument, as received from the factory, should indicate zero before being turned on. If it does not, reset the meter to read zero by means of the adjusting screw near the bottom of the meter face. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

With the instrument plugged into the proper power source, turn the power toggle switch to "ON." Allow the instrument to warm up about 30 minutes for stable operation. For precision measurements, additional time should be allowed for the reference and signal filters of the PAV to reach equilibrium temperature conditions.

QUADRATURE CHANNEL CHECK AND CALIBRATION

This calibration is necessary prior to making any measurements. The Complex Voltage Ratiometer contains a passive, standard, 90° network which permits making this calibration without the need for additional equipment. Behind the front panel door marked "PHASE CALIBRATION CONTROLS" there is a switch and a control. The switch is designated "OPER" and "QUAD CAL." With excitation voltage applied and reference level properly adjusted, the calibration may be performed as follows:

SWITCH TO CVR POSITION, & ADJ-OPER SWITCH TO OPER

1. Switch to "QUAD CAL" and "QUAD LEVEL" to first position "+".
2. Switch range selector to 1 volt scale and Function Selector to 90°.
3. Adjust the quadrature level control to obtain a null.
4. Switch the Function Selector to 0° and adjust the "QUAD PHASE" control for a null.
5. Switch Range Selector to next most sensitive position.
6. Repeat Steps 3, 4, and 5 until nulls are obtained of less than 0.5 ppm Es or Iuv (whichever is greater).
7. Switch to "OPER", close door and make measurements.

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GENERAL PHASE ANGLE VOLTMETER MEASUREMENTS

1. Switch EXC-PAV-CVR selector to the PAV position.

2. Follow instructions outlined in the Operation and Instruction Manual for VM-202, 300 microvolts type Phase Angle Voltmeter. (Section II).

3. When using the Phase Angle Voltmeter in this mode of operation, do not connect the ground wire of the PAV to ground of the CVR as this will cause a ground loop.

TO MEASURE IN-PHASE RATIO

1. 4 Terminal Network: Connect input of test item to EXC OUT terminals of CVR. HI side to red terminal; LO side to black terminal. Using the CVR Test Cable, attach red lead to HI side of test item output and black lead to LO side of test item output.

2. 3 Terminal Network: Connect input of test item to EXC OUT terminals of CVR. HI side to red terminal; LO side to black terminal. Using CVR Test Cable, attach red lead to HI side of test item output. Do not connect black lead to LO side ot test item. (Connecting this lead can cause an undesirable ground loop.) See note below.

3. Having connected the test piece as previously described, as well as applying power and excitation, set the EXC-PAV-CVR switch to the EXC position.

4. Set the Range Switch to the appropriate scale (with Function Selector in FUND) and read excitation voltage.

5. Set REFERENCE Switch to the ADJ position and adjust to red line reading on voltmeter. Reset REFERENCE Switch to OPER position.

6. Set EXC-PAV-CVR switch to CVR position.

NOTE: For testing high and low current carrying devices, see Description of Terminals-Connectors Section (EXC OUT).

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7. Set the Function Selector to the 0° position.

8. Adjust ratio box setting (including polarity switch) to null the in-phase component on the lowest scale possible without illuminating the overload light.

9. Adjust the ratio box so as to disturb the null by approximately full scale on the Phase Angle Voltmeter. Note this setting and return to the null setting (Step 8).

10. Switch Function Selector to 90° position and vary the ratio box between the null setting (Step 8) and the offset ratio noted in Step 9 above. This variation should not cause a change in quad reading. If a change is observed, adjust the Phase Dial to a position such that no change in voltage is observed while varying the Ratio Box between these two settings. Set the Ratio Box back to the previously determined null position.

~~11. Repeat Step 6.~~

12. Set Function Selector to 90° position and using both fine and coarse controls inject a quadrature voltage to obtain a null reading on the lowest possible scale without illuminating the overload light.

13. Repeat Steps 8 and 12 alternately until both quad and in-phase null levels are less than 1 ppm of the excitation voltage level.

14. The Ratio Box reading indicates precisely the in-phase ratio.

TO MEASURE QUAD

1. Following the steps outlined above under In-Phase Ratio Measurement, set Function Selector to 90°.

2. Turn quadrature coarse switch to OFF.

3. Read voltmeter at the most sensitive scale possible.

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4. This reading is the quadrature voltage.

TO MEASURE PHASE ANGLES

1. Following Steps 1 through 14 outlined in the procedure to measure in-phase ratio, set the Function Selector to the ∠ SET position.

2. Set RADIANS-DEGREES switch to RADIANS position.

3. Set the Angle Scale Set selector to the appropriate position.

   NOTE: If the in-phase voltage (in-phase ratio X EXC voltage) is greater than 10V, use the HI position of the switch. If the in-phase voltage is less than 10V, use the LO position.

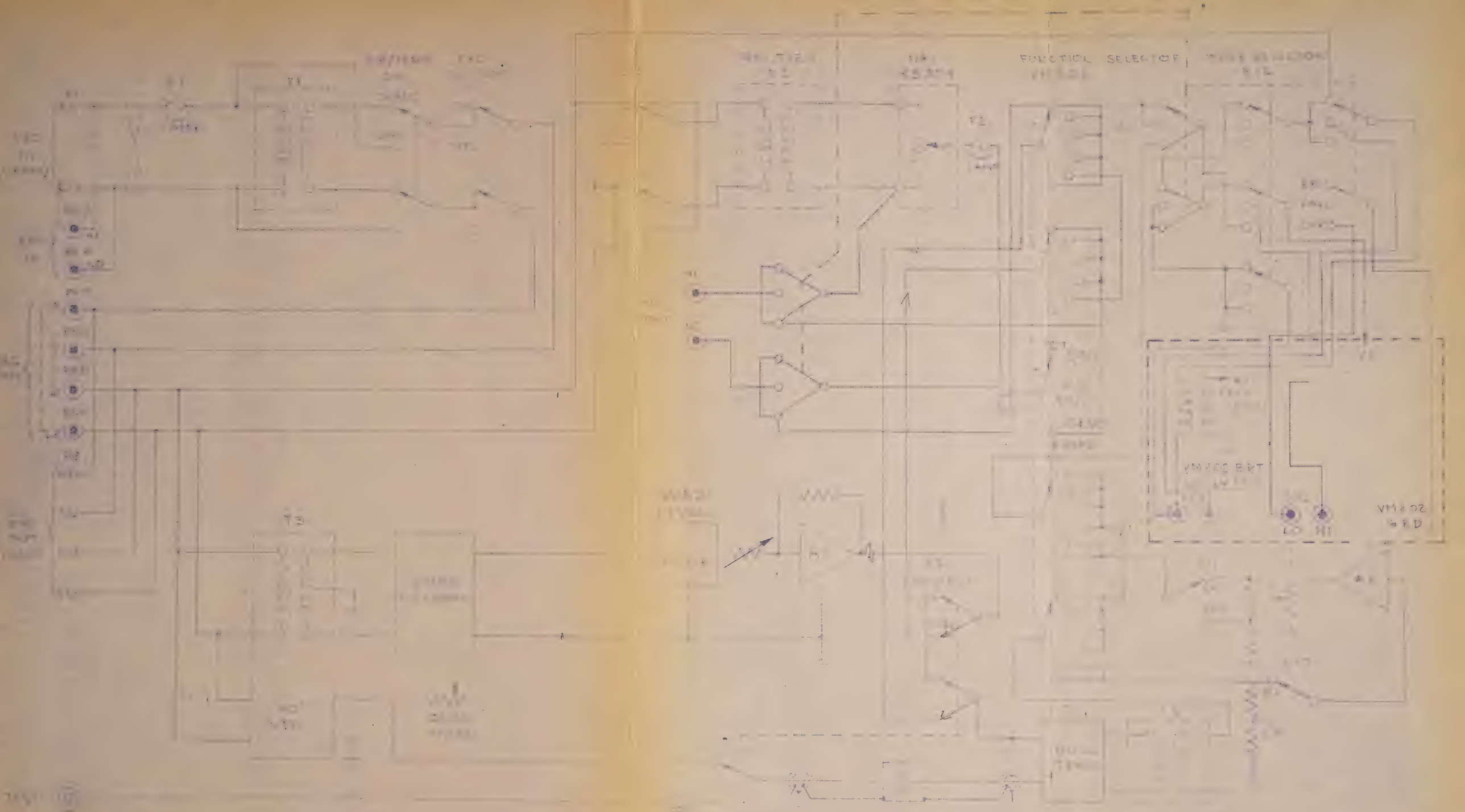
4. Set the Range Selector to the highest decade position (i.e., 10, 1, .1) where a full scale meter deflection can be obtained by adjusting the inner knob of the Angle Scale Set Selector.

5. Without rotating the Range Selector, slide the RAD/DEG scale on the Range Selector to align the 1 radian position with the voltage range selected in Step 4.

6. Switch Function Selector to ∠ READ. Set Range Switch to the most sensitive scale possible (without disturbing the angle scale to voltage scale relationship).

7. Read the voltmeter directly in angle or radians (depending on setting of Angle Scale Set Switch).

   CAUTION: TO ASSURE ULTIMATE ACCURACY IN INTERPRETATION OF MEASUREMENTS, OCCASIONAL MONITORING OF THE EXCITATION VOLTAGE IS SUGGESTED. THIS MAY BE PERFORMED BY SWITCHING THE EXC-PAV-CVR SWITCH TO THE EXC POSITION~



CVR-551
FUNCTIONAL SCHEMATIC
FIGURE 1

SECTION II

PHASE ANGLE VOLTMETER

OPERATING AND INSTRUCTION MANUAL FOR VM-202 SERIES 300 MICROVOLT TYPE PHASE ANGLE VOLTMETER

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Plainview New York

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DEGREES
OVERLOAD
POWER
RANGE
FUNCTION
0°
90°
180°
270°
FUND.
TOTAL
STD
VTVM
PHASE
ANGLE
VTVM
EXT REF
REF ADJ
ON
OFF
SIGNAL
REFERENCE
EXT
ADJ
LINE
MILLIVOLTS
VOLTS
PHASE ANGLE VOLTMETER

TABLE OF CONTENTS

	PAGE
I. SPECIFICATION	1.1
II. GENERAL DESCRIPTION	2.1
Power Line Voltage and Cable	2.1
III. OPERATING INSTRUCTIONS	3.1
CONTROLS	3.1
On-Off	3.1
Range Switch	3.1
Terminals	3.1
Function Selector	3.1
Reference Selector	3.2
Frequency Adjustment	3.2
DISPLAYS	3.2
Meter	3.2
Phase Angle Dial	3.2
Overload Lamp	3.3
FUSE	3.3
OPERATION	3.3
To Measure Voltage	3.3
To Measure Phase Angle	3.4
Reference Adjustment	3.4
Phase Shifter Adjustment	3.4
Phase Angle Measurement Using Calibrated Phase Shifter	3.5
Phase Angle Measurement Using E cos θ Characteristic	3.5
To Measure the In-Phase and Quadrature Component of a Signal	3.5
IV. THEORY OF OPERATION	4.1
General	4.1
Amplifier	4.1
Reference Channel	4.2
Phase Sensitive Rectifier	4.2
Phase Shifter	4.3
Filters	4.3
Power Supplies	4.3

TABLE OF CONTENTS (CONT'D.)

V.	MAINTENANCE	5.1
	Cover Removal	5.1
	Crystal Diode Replacement	5.1
	Tube Replacement	5.1
	Fig. 5.1 Block Diagram	5.2
	Fig. 5.2A Circuit Schematic (60 & 400~ only)	5.3
	Fig. 5.2B Circuit Schematic	5.4
	Fig. 5.3 Filter Characteristic	5.5
VI.	CALIBRATION TEST PROCEDURE	6.1
	Voltage Calibration	6.1
	Phase Alignment	6.3
	Frequency Response Adjustment	6.6
	Fig. 6.1 Top View Photograph	6.8
	Fig. 6.2 Bottom View Photograph	6.9
	Replacement Parts List	6.10
VII.	WARRANTY	7.1

SPECIFICATION

General: The models covered by this specification are single frequency units in the range of 30 cps to 10 kc. The reference adjust knob on the front panel of the instrument and the nameplate identify the frequency of operation. These units are characterized as follows:

Model 202R	No Filters
Model 202AR	Filter in signal channel only
Model 202BR	Filters in signal and reference channel

NOTE: The subscription "T" indicates that there is built in reference isolation transformer.

Additional optional features available include: Shielded Input Isolation Transformer, Rear Panel Connectors and Custom Front Panels

Voltage Range: Full-Scale reading: 300 microvolt to 300 volts in 13 separate ranges.

Frequency Range: Response for phase sensitive positions is at the specified frequency of the reference. (See also Harmonic Rejection.) For standard Voltmeter operation response is that of selective filters when used on broadband from 10 cps to 50 kc.

Accuracy at frequency of operation:
2% as a voltmeter
3% of full scale angle as a phase angle voltmeter using E cos θ characteristic
1° calibrated phase shifter

Signal Input Impedance: Nominally, 10 Megohms. (With optional shielded isolation transformer for balanced input, 300 K approx. at 400 cps. If resonated the input impedance of transformer is approx. 1.0 Megohms at 400 cps.).

Reference Input Impedance: 100 K ohms

Reference Voltage: 0.25 to 130 volts. (With reference input isolation transformer, minimum input is 1.25 volts).
Note: In order to reach "REDLINE" (see Operating Instructions) 1.3 volts is required for direct input and 6.5 volts for transformer

input. However, operation may be obtained with minimum values stated above.

Reference Selector: External reference at frequency of operation. One side grounded or isolated power line reference for 400 or 60 cps power.

Calibration: Zero center voltmeters read RMS of Sin Wave. Line or voltage scales 3-0-3 and 10-0-10 reads E cos θ (angle between signal and reference as phase angle meter). Phase Angle dial calibration 0^{o} to 90^{o} in 1^{o} divisions. Four position Quadrant Selector.

Overload: Overload alarm lamp set at 5 X full scale voltage.

Power: 115V ±10%, 60-400 cps. Approximately 60 watts at 60 cps.

Noise: Less than 5 microvolts for low impedance input.

Nulling Sensitivity: Less than 1 microvolt in phase sensitive mode.

Harmonic Rejection: Greater than 55 db with filters.

SECTION II

GENERAL DESCRIPTION

The VM-202 series Phase Angle Voltmeters are a truly unique multifunctional instrument which will function as a sensitive broad band vacuum tube voltmeter, and, at a rated frequency: A phase angle meter, i.e., a meter measuring in-phase signals (E cos θ) and quadrature signals (E sin θ); A phase sensitive null indicator; An impedance meter; A power factor meter.

High input impedance (10 megohms) and voltage ranges from 300 microvolts full scale to 300 volts, make the instrument highly suitable for use on high impedance and low level circuits.

Power Line Voltages and Cable

The instruments are normally wired for use on 115 volt, 60-400 cps power. Power consumption is approximately 60 watts at 60 cps. A three conductor power cable with a polarized connector is supplied with the instrument when both signal and reference channel have built in isolation transformers. All other instruments receive their chassis ground through either the signal or reference inputs.

CAUTION: TO AVOID THE PITFALLS OF GROUND LOOPS DUE TO MULTIPLE POINT GROUNDS REFER TO THE SECTION IN THE APPLICATION NOTES (APPENDIX 2), TREATING THIS SUBJECT.

SECTION III

OPERATING INSTRUCTIONS

CONTROLS

On-Off

This toggle switch turns the instrument on as indicated by the power ON pilot light.

Range Switch

This switch selects the full scale voltage indicated at each position.

Terminals

Input terminals for both the reference and signal inputs are marked with a "G" for the ground terminal and are colored Red for the high side of the input. These posts, which are on standard 3/4" spacing, will accommodate banana plugs, wire, or alligator clips.

CAUTION: MAXIMUM INPUT SIGNAL MUST NOT EXCEED 1000 VOLTS AND MAXIMUM INPUT REFERENCE MUST NOT EXCEED 600 VOLTS (COMBINED PEAK A.C. AND D.C. LEVELS). HIGHER VOLTAGES WILL BREAK DOWN THE INPUT CAPACITORS IN THE INSTRUMENT.

Function Selector

The "Function Selector" is used to select the desired mode of operation for the instrument. In the four Phase Angle Voltmeter positions, the instrument is connected so as to read a voltage E cos θ, where θ is defined as the angle between the signal vector and the reference vector. The "Function Selector" then selects the quadrant over which the calibrated phase shifter will operate. Thus the total angle shifted in degrees will be either 0^{o}, 90^{o}, 180^{o} or 270^{o} plus the reading of the phase dial.

In the position marked "FUND" the instrument functions as a standard voltmeter and reads the total vector voltage of the fundamental signal.

In the position marked "TOTAL" (or just STD VTVM for the model 202R), the signal filter is removed and the instrument functions as a standard voltmeter reading the entire input signal including harmonics.

Reference Selector

This switch is used to select either an external reference or a line reference (for the case where the power line frequency is 60 cps or 400 cps and corresponds to the rated frequency.) In the position marked "ADJ." the reference is connected to the voltmeter and can be set to a reading from 1 to 10 on the 10 scale by using the knob marked "REF ADJ." The function selector should be in the "STD" position when making this adjustment. A red line is provided at mid-scale as a convenient point at which the reference level may be set.

NOTE: Phase measurements may be made with less than "Red Line Level Set". A minimum safe value, however, is a reading of 1 on the 10 scale. (See also Section I "Specifications" page 1.1, "Reference Input").

The adjustment of level for the "LINE" reference has been made at the factory and corresponds to the red line condition.

NOTE: Turnover of the line plug will shift the reference phase 180° when using the "LINE" reference.

Frequency Adjustments

This screw driver adjustment, R71, is located on the rear of the instrument and is used to rezero the phase measuring dial as described under Phase Shifter Adjustment, Page 3.4, Section III.

DISPLAYS

Meter

The meter is a zero center d.c. milliammeter calibrated to read the RMS value of a sine wave. For "STD VTVM" reading, the needle deflects to the right. For "Phase Angle VTVM" reading the meter deflection may be either left or right.

CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE CAN OCCUR IF THE SIGNALS ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

Phase Angle Dial

This dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter with the particular quadrant

selected by the "Function Selector." The actual calibration of this dial is non-linear. For this reason, should the dial ever be removed, the procedure under Phase Angle Dial Positioning of Section V should be followed when reassembling.

Overload Lamp

The lamp marked "Overload" lights whenever the signal exceeds a prescribed level. This indication warns of impending amplifier overload and the attendant inaccuracies which will occur when large, saturating signals are present. The overload indicator is factory set at approximately five times full scale. Amplifier overload actually occurs around ten times full scale.

FUSE

The fuseholder mounted on the back of the instrument contains a standard 1 amp cartridge fuse.

OPERATION

The instrument as received from the factory should indicate zero before being turned on. If it does not, reset the meter to read zero by means of the adjusting screw near the bottom of the meter face. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

With the instrument plugged into the proper power source, turn the toggle switch to "ON." Allow the instrument to warm up about 15 minutes for stable operation. For precision phase measurements, additional time should be allowed for the reference and signal filters to reach equilibrium temperature conditions.

The series 202 instruments are all characterized by being designed for single frequency measurements. The use of selective filters in conjunction with an R-C phase shifter results in a phase shift and amplitude characteristic which is a function of the frequency of the input signal. The filter characteristic is shown in Figure 5.3.

CAUTION: BEFORE MAKING PHASE OR VOLTAGE MEASUREMENTS REVIEW SECTION ON GROUNDING TECHNIQUES IN APPLICATION NOTES.

To Measure Voltage

1. Set the range switch to the appropriate scale and the function selector to the "STD **VTVM**" position. The reference selector must be in either the "EXT REF" or "LINE REF" position.

2. Connect the voltage to be measured to the signal input terminal.

3. Read the voltage from either the 0-10 scale or the 0-3 scale using the proper scale factor as determined by the range selector position.

   It will be noticed that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to near zero.

   Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup. Twisted and/or shielded cable will reduce the effect although the cable capacity could serve to load the source. Care must also be taken to insure that ground loops do not exist by virtue of the signal and reference grounds which will result in erroneous readings. (See Application Notes in Appendix 2 for a discussion of this problem.)

To Measure Phase Angle

Reference Adjustment

1. With instrument turned on connect the reference to the reference input. "Function Selector" should be in either "Fund" or "Total" positions.

2. Turn the reference selector to "ADJ" and adjust the "REF ADJ" knob until the meter reads on the red line. Return the selector to the Ext. position for all further measurements. For less than red line see "Reference Selector" Page 3.2, Section III.

Phase Shifter Adjustment

1. This adjustment is factory set and should seldom need to be touched except following servicing and tube replacement. Using a signal source equal to full scale on any range greater than 0.3 volts, connect the signal input into the reference channel, and adjust the reference level in accordance with the preceeding.

2. a. Place Function Selector in 0° position and the Phase Angle Dial at 90°.

   b. Place Function Selector in 90° position and the Phase Angle Dial at 0°.

   c. If the meter does not read zero for both these tests,

use the back panel screw driver adjustment, R71, to provide a zero which is the best compromise for both cases. In general, once this setting is made there is little reason to readjust the control unless special measurements are made such as are described later in Section III, and in the appended Application Notes.

The rezeroing of the Phase Shifter will in no way affect the accuracy of the instrument.

Phase Angle Measurement Using Calibrated Phase Shifter

1. With reference adjusted to the red line and phase shifter properly zeroed, connect the input signal to the voltmeter and use the meter scale providing a maximum reading in the standard position.

2. Switch the function selector to a suitable Phase Angle Volt meter position and turn the degrees dial to read a near maximum.

3. Switch the function selector 90°. Turn the degrees dial until the meter reads zero. Switch the function selector to a position (0, 90, 180 or 270), which gives a meter deflection to the right. The phase angle is then the sum of the function selector angle plus the dial angle. This rule eliminates the possibility of ambiguity.

Phase Angle Measurements Using E cos θ Characteristic

Accurate measurements of phase angle can also be made using the E cos θ or E sin θ characteristic. Voltage measurements are made of the in-phase or quadrature component and of the fundamental signal (STD VTVM position). The quotient will then be th cosine or sine of the unknown phase angle. Trigonometric tables slide rule, or the graphs included in the appended Application Notes may be used for converting to degrees. The accuracy achie able using this technique depends upon the procedure and for that reason it is suggested the Application Notes be reviewed before using this method.

To Measure the In-Phase and Quadrature Component of a Signal

1. With the reference level set, place function selector in 0 degree position. Set the phase shift dial at zero degrees.

2. The meter now reads the in-phase component of a signal. This is also E cos θ where θ is the angle between the reference and signal.

3. Switch the function selector 90°. The meter now reads the quadrature component or E sin θ. In general, one of these components is usually much smaller than the other and for

greater accuracy it is convenient to change the range of the instrument. This can be done until the overload lamp lights thereby warning of an impending overload condition. This light indicates that the total signal exceeds five (5) times the full scale value. Measurements can be made for overloads up to 10 times full scale at which time amplifier clipping takes place. Measurements under all these conditions will be most accurate if the zeroing process described in the Application Notes is followed.

SECTION IV

THEORY OF OPERATION

General

The block diagram of Figure 5.1 will serve to illustrate the principle of operation of the Phase Angle Voltmeter.

The input signal to be measured passes through the first section of the range multiplier switch to the grid of a cathode follower (1/2 of V1). For low signals (up to .3 volts) the signal goes directly to the grid of V1. For the remaining scales the signal is attenuated by a factor of one thousand. The output of the first cathode follower then passes through the second section of the range multiplier switch to the grid of a second cathode follower which drives the signal channel filter. The range multipliers are arranged so as to always have a full scale voltage of approximately 300 microvolts applied to the grid of V2.

The amplifier consisting of V2, V3 and V4 feeds the rectifier section of the voltmeter. This part of the circuit is arranged as a ring type demodulator (phase sensitive rectifier) when used as a Phase Angle Voltmeter or as a conventional full wave rectifier circuit where used as a conventional voltmeter. In both cases, heavy feed back is used around the silicon diodes and amplifier to minimize the non-linear forward characteristic of the diodes as well as the calibration shift normally associated with tube ageing.

The Reference Channel consists first of a potentiometer level control followed by a cathode follower V8. The cathode follower feeds into the reference filter which in turn goes directly into the first reference channel amplifier consisting of 1/2 of V4 and V5. This amplifier is a multi-loop feed back amplifier which provides a low impedance source for driving the second reference amplifier which is identical to the first reference amplifier. The second amplifier then drives the phase sensitive rectifier when the instrument is used as a Phase Angle Voltmeter.

Amplifier

The main amplifier consists of an input pentode V2 driving a boot strap amplifier consisting of V3 and 1/2 of V4. Local feed back around the triode section serves to provide stabilization for this stage with only a slight reduction in overall loop gain. The output of the amplifier drives a cathode follower, 1/2 of V4, to present a low impedance to the meter rectifier. Gain calibration of the amplifier is accomplished by potentiometers R18 and R72. The

output of the amplifier drives, in additon to the phase sensitive rectifier, an indicator I2 which is biased by means of R26 so as to light when the signal level exceeds five times the full scale meter reading. Thus, it is possible to measure very small out of phase signals in the presence of large non-indicating in-phase signals. Under special conditions, measurement with as much as 10 X full scale overload can be made. This type of overload will not damage the meter movement in any way.

Reference Channel

The reference channel gain is adjusted by means of level pot R52. With the reference set at the adjust position, a small signal proportional to the reference level is derived from the cathode of V7 in the first reference amplifier and fed to the input of the signal amplifier. The level is then adjusted to read approximately half scale as indicated by the red line. For measurements involving a high ratio of out-of-phase to in-phase signal it is frequently desirable to use an even greater reference level so as to minimize saturation effects in the phase sensitive rectifier itself. The scale allows an increase of 2:1 over the red line. Operation in excess of this level is not recommended except under special circumstances. The zero shift which occurs when operating above the red line reference level can easily be removed by using the Frequency Trim Control R-71 in the manner described in Section III.

Phase Sensitive Rectifier

The phase sensitive rectifier circuit is a conventional ring demodulator. Its operation can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through cathode resistor R18 and then the other end on the reverse cycle of the reference. The signal is therefore synchronously rectified through the meter movement. If the reference and signal are in phase, the average value will be a maximum and the meter will read a maximum. If the signals are 90 deg. apart the average will be zero and no reading will result. The equation governing this is:

$$I_{meter\ (avg)} = K\,E\cos\theta$$

where K = proportionality constant
E = rms of signal
θ = angle between signal and reference

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Under special conditions, such as are described in the appended Application Notes the reference level is increased to improve accuracy for high signal

levels. Measurements at the quadrature null point (θ = 90 deg.) are unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. All other frequencies are rejected except for signals very near to a response frequency. Here, the meter movement will oscillate between plus and minus maximums as the two near frequencies are alternately in-phase and 180 deg. out-of-phase. Response for this type detector to odd order harmonics will never be greater (usually less depending upon phase angle), than the fundamental response multiplied by a factor of 1/n where n is the order of the harmonic. Where a signal channel filter is used, there is of course, essentially no response to harmonics in the signals.

The effect of reference harmonics is much less important than that of signal harmonics because the harmonic content can never do more than shift the point at which the diodes start to conduct. Expressed otherwise, there is an equivalent error in degrees which results from harmonic in the reference channel. For measurements using the phase shifter the error can be removed by trimming. For measurements using the E cos θ characteristic that effect is small because the meter reading as a function of current integrated over an entire cycle and the small error produced by distortion has a correspondingly small effect on the total current.

When used as a standard VTVM the phase sensitive rectifier is switched to that of a full wave rectifier. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Phase Shifter

The Phase Shifter used is an RC type in which two half lattice sections are used to excite taps on a potentiometer. This type of device inherently has a non-linear change in phase shift for an input shaft rotation which results in the non-linear dial calibration used. The output of this device also varies in amplitude by a factor of 0.707. This variation causes substantially zero error in the instrument. For some instruments trimming elements are used to improve the phase shifter linearity. These are designated as R on the schematic.

Filters

The filters used in the equipment are a stabilized version of the commercial filter having the same type number.

Power Supplies

The power supply furnishes a well filtered high voltage d.c. for

OPT REAR CONNECTOR

OPT. REAR CONNECTOR

EXC OUT

SEE NOTE 2

J202 P2

S12, D3, WIPER D-760106

S12, D2, WIPER D-760106

S12, D3, POS 2 D-760106

S12, D2, POS 2 D-760106

J203 P3

S12, A1, POS 1 D-760106

S4, A1, POS 5 #6 D-760106

J204 P4

S4, B1, WIPER D-760106

S4, B2, WIPER D-760106

S4, A2, POS 5 #6 D-760106

S4, A1, WIPER D-760106

EXC IN

S206

S207

S213

T206

T207

RB504

F202

#C204, R215 SELECT AT TEST

RB504 OUTPUT

S209

QUAD ADJ.

A1

A2

A3

B1

SEE NOTE 2

T208

T209

C210 .24

S210

S211

S212

ANGLE SCALE SET

D-760107 QUAD. AMPL

J404 J403 J402 J401

J205 P205

OPT REAR CONNECTOR

TEST

J201

QUAD NETWORK

QUAD LEVEL (COARSE)

S208 (C1)

(C2)

T210

S208 (B)

S208 (A2)

S208 (A1)

R220 50K LC

R202 150K D.C

R203 50K D.C

R204 50K D.C

R205 50K D.C

R206 150K D.C.

R207 5K

R208 5K

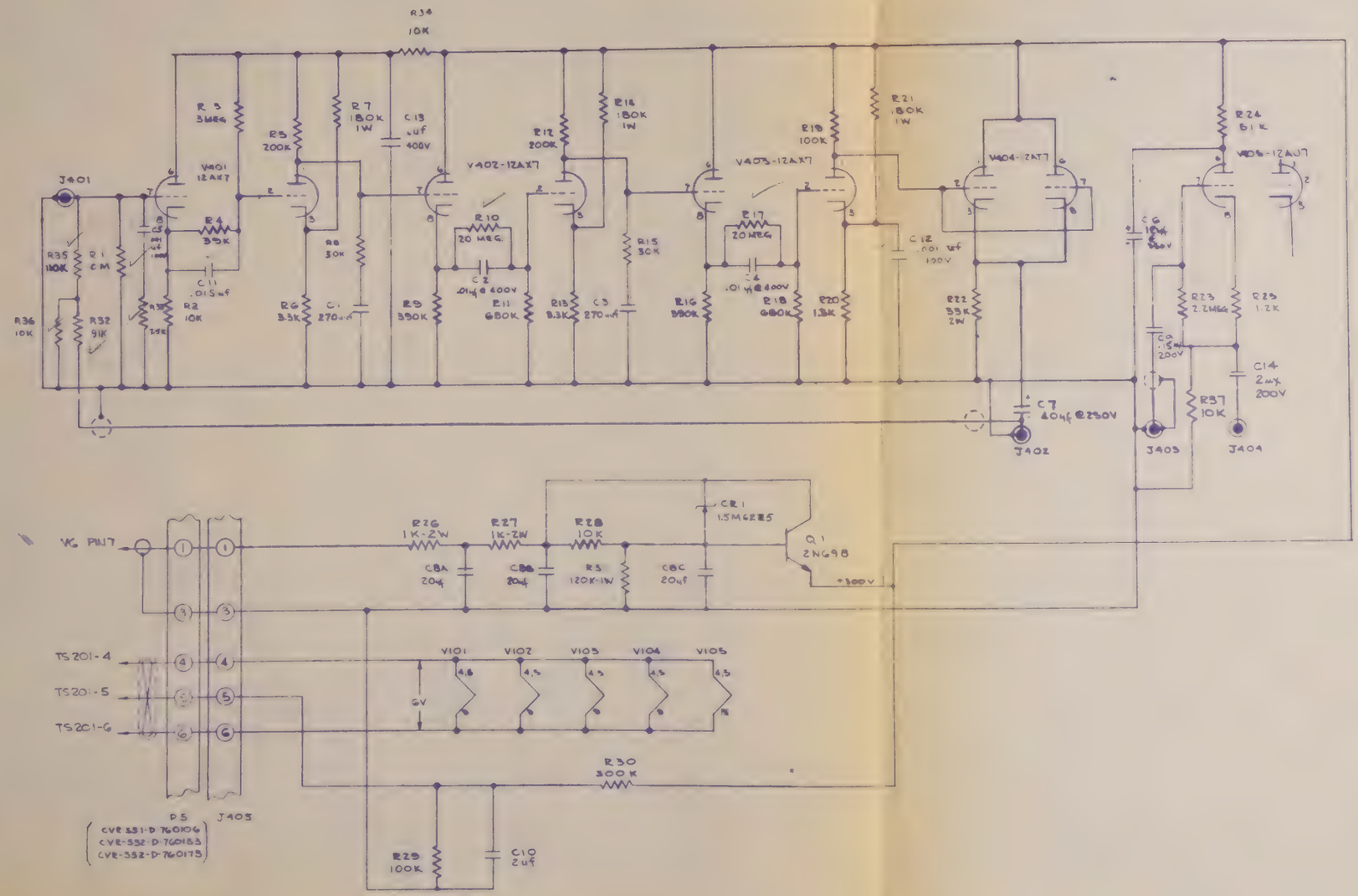
QUAD LEVEL (FINE)

R214 500

QUAD PHASE

NOTES.

1. ALL SWITCHES SHOWN AS VIEWED FROM FRONT PANEL.
2. (3)- DENOTES 3 CONDUCTOR, TWISTED SHIELDED WIRE WITH CONDUCTORS TIED TOGETHER AT TERMINATIONS.
   (8)- DENOTES 2 CONDUCTOR, TWISTED SHIELDED WITH CONDUCTORS TIED TOGETHER AT TERMINATIONS.



NOTES:
1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE 1/2 WATT
2. ALL COMPONENTS, TUBES ETC. ARE ASSIGNED "400" DESIGNATIONS, e.g. R1 IS R401

all stages except V1 which uses, in addition, a voltage regulator. Filaments are all a.c. except for V1, V2, V3 and V4 which are supplied with a well filtered d.c. voltage from a bridge rectifier CR 5.

SECTION V

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. All alignment procedures are described in Section VI.

Cover Removal

To remove top cover, remove six top screws and four side screws. The bottom cover can easily be taken off by removing eight bottom screws.

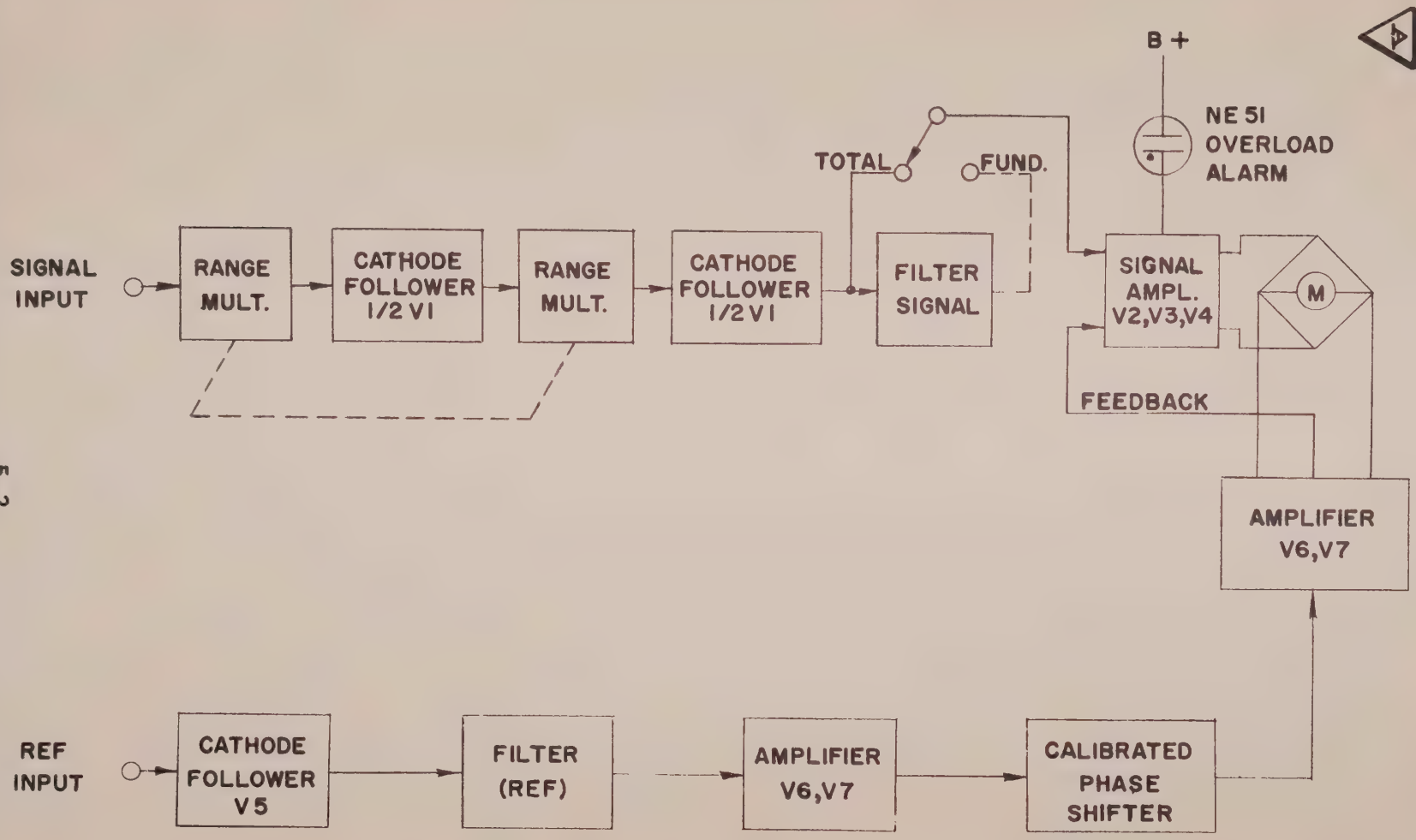
Crystal Diode Replacement

When replacing crystal diodes, care must be taken to avoid damage to the diode through excessive heating while soldering. A simple precaution is to clip an alligator clip to the lead of the diode being soldered in place. Be sure to use a well-tinned soldering iron.

Tube Replacement

No circuit in the VM-202 series is critical to tube replacement. However, for maximum accuracy the calibrations listed under "adjustments" should be checked when tubes are changed.

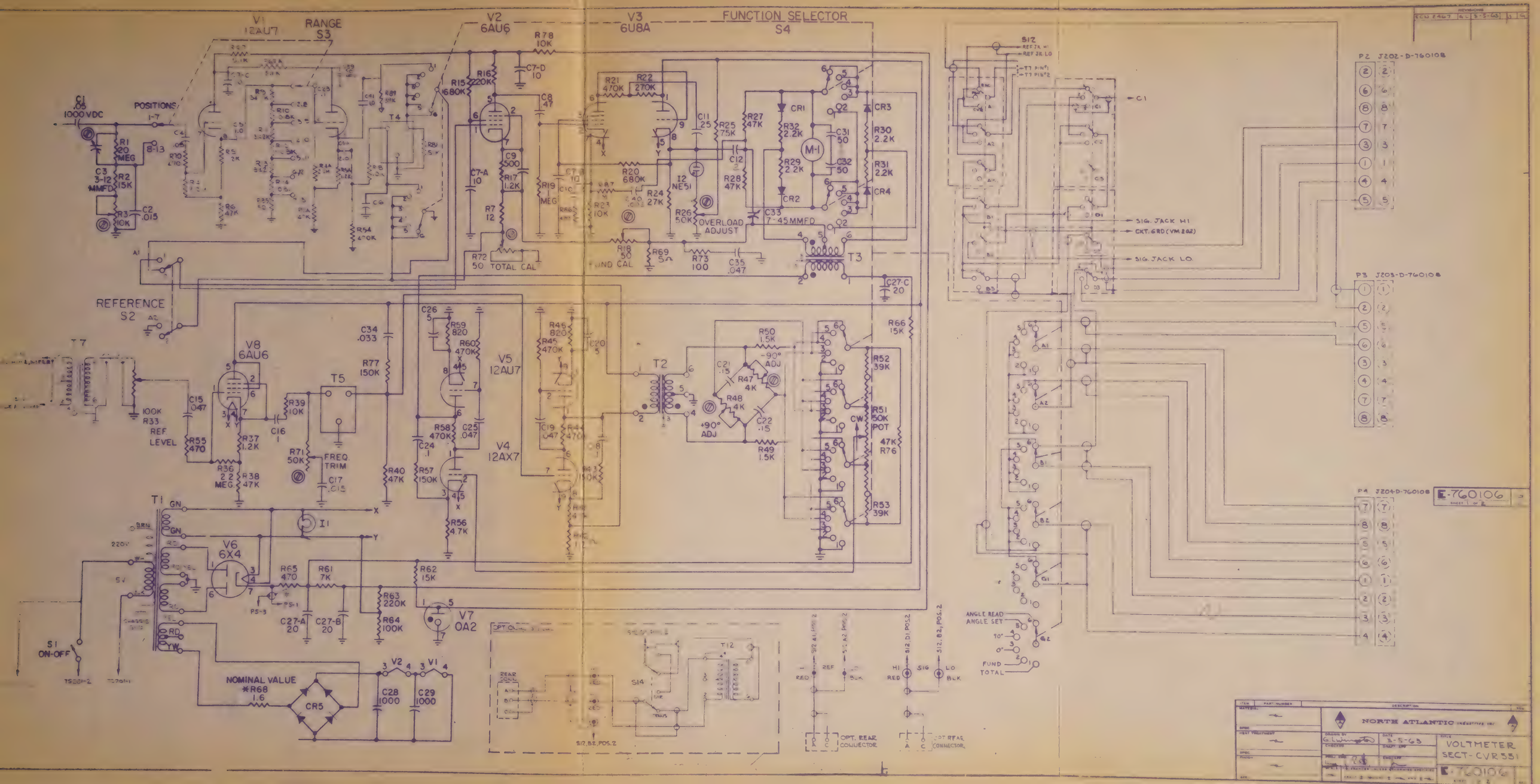
NORTH ATLANTIC industries, inc.
terminal drive, plainview, l. i., n. y., overbrook 1-8600

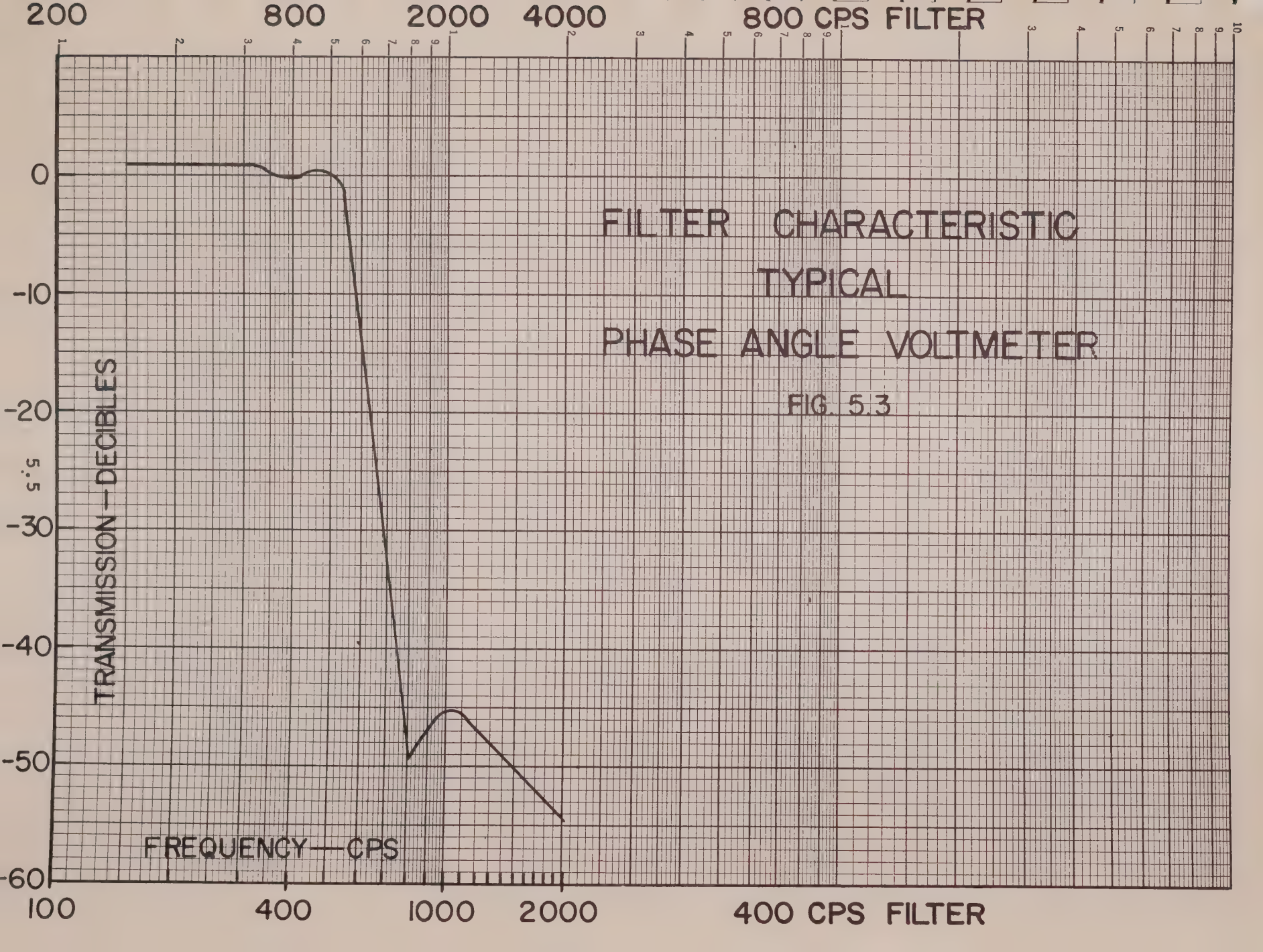


BLOCK DIAGRAM

VM 202 BR 300 MICROVOLT

FIG 5.1


V1 12AU7
RANGE S3
V2 6AU6
V3 6U8A
FUNCTION SELECTOR S4
POSITIONS 1-7
C1 .05 1000 VDC
R1 20 MEG
R2 15K
R3 10K
C2 .015
C3 3-12 MMFD
R78 10K
R16 220K
R15 680K
C7-D 10
C8 .47
C7-A 10
C9 500
R17 1.2K
R7 12
R72 50 TOTAL CAL
R19 1 MEG
R21 470K
R22 270K
R20 680K
R24 27K
R23 10K
R18 50 FUND CAL
R69 5n
R73 100
C35 .047
I2 NE51
R26 50K OVERLOAD ADJUST
C11 .25
R25 7.5K
C12 2
R28 47K
R27 47K
CR1
CR2
CR3
CR4
R32 2.2K
R29 2.2K
R30 2.2K
R31 2.2K
C31 50
C32 50
C33 7-45 MMFD
M-1
Q2
T3
C27-C 20
REFERENCE S2
T7
100K R33 REF LEVEL
C15 .047
R55 470
R36 2.2 MEG.
R38 47K
R37 1.2K
C16 1
V8 6AU6
T5
R39 10K
R71 50K FREQ TRIM
C17 .015
R40 47K
C34 .033
R77 150K
C26
R59 820
R60 470K
C25 .047
R58 470K
C24 .1
R57 150K
R56 4.7K
V5 12AU7
V4 12AX7
R46 820
R45 470K
C20
C19 .047
R44 470
R43 150K
T2
R50 1.5K -90° ADJ
C21 .15
R47 4K
R48 4K
+90° ADJ
C22 .15
R49 1.5K
R66 15K
R52 39K
R51 50K POT
CW
47K R76
R53 39K
T1
GN
BRN
220V
RD
YW
I1
V6 6X4
R65 470
R61 7K
R62 15K
R63 220K
R64 100K
PS-1
PS-3
C27-A 20
C27-B 20
V7 0A2
S1 ON-OFF
TS201-2
TS201-1
NOMINAL VALUE
*R68 1.6
CR5
C28 1000
C29 1000
S12
REF JK HI
REF JK LO
T7 PIN 1
T7 PIN 2
SIG. JACK HI
CKT. GRD (VM 202)
SIG. JACK LO.
P2 J202-D-760108
P3 J203-D-760108
P4 J204-D-760108
ANGLE READ
ANGLE SET
10°
0°
FUND
TOTAL
REAR CONN
S14
T12
S12, B2, POS. 2
S12 A1, POS. 2
S12 A2, POS. 2
S12 B1, POS. 2
S12 B2, POS. 2
1 RED
2 REF
3 BLK
HI RED
SIG
LO BLK
OPT. REAR CONNECTOR
OPT REAR CONNECTOR
E-760106
NORTH ATLANTIC INDUSTRIES INC.
VOLTMETER
SECT-CVR351
E-760106


200
800
2000
4000
800 CPS FILTER
0
-10
-20
-30
-40
-50
-60
TRANSMISSION — DECIBLES
FREQUENCY — CPS
100
400
1000
2000
400 CPS FILTER
FILTER CHARACTERISTIC
TYPICAL
PHASE ANGLE VOLTMETER
FIG. 5.3

SECTION VI

CALIBRATION TEST PROCEDURE

The adjustments described in this section require precision test equipment in order to achieve rated accuracy and for that reason it is recommended that the instrument be returned to the factory, or, submitted to a qualified instrument lab if this kind of readjustment is necessary.

Reference is made to Figures 6.1 and 6.2 showing location of all adjustments (pages 6.8 and 6.9).

VOLTAGE CALIBRATION

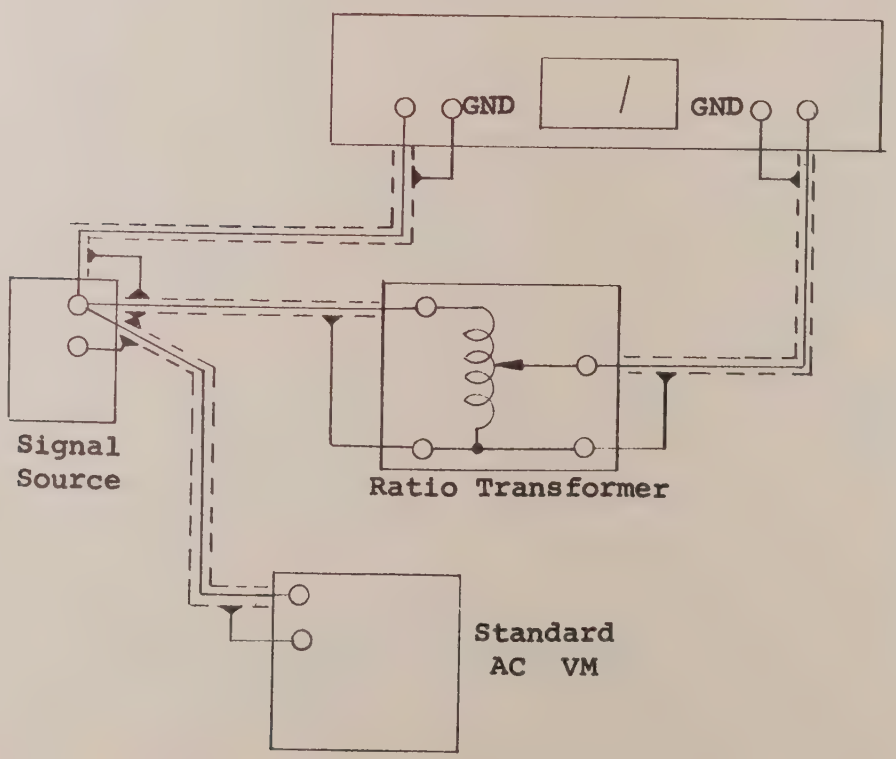
Equipment Required

1. Variable voltage signal source capable of generating frequency of operation for the particular unit under test. Accuracy of frequency of the signal source should be ±1/2%. Output capability at least 20 volts, (e.g., Hewlett-Packard Model 200 CD).

2. Standard AC Voltmeter having accuracy of ±3/4% of full scale reading or better, (e.g., Poly Ranger Sensitive Research Corp. Model U-88).

3. North Atlantic Industries Model RB-503 Ratio Transformer or equal.

Connect Instrumentation as shown:



Procedure

1. Set output of frequency source to 10.00 volts as read on Standard Meter.

2. Set Reference Selector switch to "Adjust". Adjust Reference level to red line value.

3. Set Reference Selector to "External" and Function Selector to "Fundamental".

4. Set Range Selector to 0.1.

5. Set Ratio Transformer to give output of 0.1 volts.

6. Adjust R18 (Fundamental Calibrate Pot located on top of chassis), until meter reads exactly full scale. Lock jam nut on R18.

7. Switch Function Selector to "Total" and adjust R72 (Total Calibrate Pot located on right side of chassis) for exactly full scale reading. Lock jam nut on R72.

8. Set Function Selector to "0°" and turn phase dial until meter reads exactly zero.

9. Set Range Switch to 1.0.

10. Set Ratio Transformer to provide 1.0 volts out.

11. Adjust C3 (Trimmer Capacitor mounted on Range Switch) until meter needle moves approximately half the number of scale divisions to zero.

12. Switch Function Selector to "Fundamental" and adjust R3 (accessible through large hole in side of chassis under Range Switch), until meter pointer moves half the number of divisions between initial reading and full scale.

13. Repeat steps 11 and 12 until meter reads exactly zero when Function Selector is in "0°" position and exactly full scale when function selector is in "Fundamental" position.

    Note: 1) There is considerable interaction between R3 and C3 and several adjustments may have to be made to set these controls to correct

position. Lock R3 and glyptal C3 when this alignment is complete.

Note: 2) This test, as well as others to follow, should be performed with meter in vertical plane.

PHASE ALIGNMENT

Equipment Required

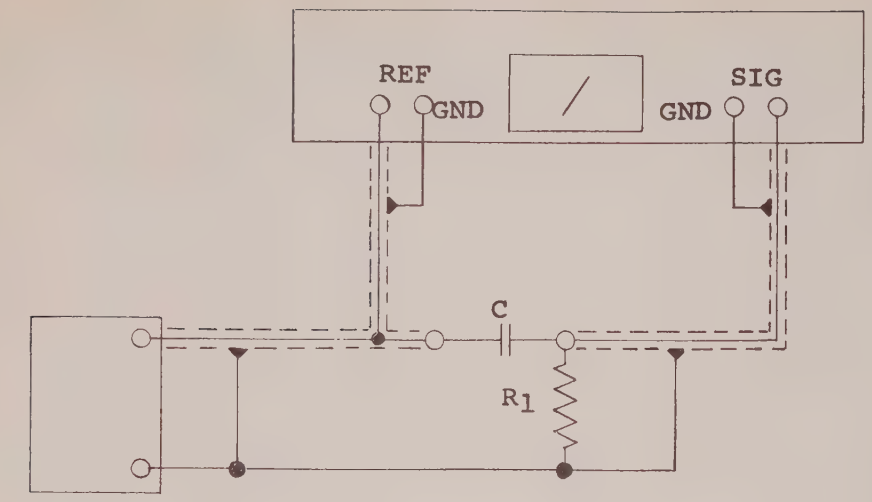
1. Variable voltage signal source capable of generating frequency of operation for particular unit under test (e.g., 60 cps, 400 cps, 800 cps, 1 KC, 10 KC, as applicable). Accuracy of the frequency of the signal source should be ±1/2%. Output capability at least 20 volts (e.g., Hewlett-Packard Model 200 CD).

TABLE I

Operating Frequency	R_1 (Ohms)	C (MFD)	R_2 (Ohms)
60 cps	120	0.01	270,000
400 cps	180	0.001	390,000
800 cps	91	0.001	200,000
1,000 cps	91	0.001	160,000
1,500 cps	47	0.001	100,000
10,000 cps	91	0.0001	160,000

NOTE: The impedances of the above may be interpolated between frequencies shown.

Remove the top cover of the instrument. Connect the signal source, capacitance, and resistor as shown in the block diagram below.



Align phase dial on phase shifter pot R51 as follows:

1. Turn power off.

2. Set Function Selector to any phase sensitive position.

3. Use an ohmmeter to place the wiper of R51 exactly on the CCW tap point. Loosen dial clamping screw and rotate Phase Dial until dial reading is exactly 90°. Tighten clamping screw. Reconnect ohmmeter to CW tap point and rotate phase dial until wiper of R51 is on CW tap point. Dial should now read zero degrees. If not, reposition dial so as to achieve the best compromise reading between the two taps. For example, if the zero degree point reads low, the 90° point should read high by the same amount. Fully tighten knob set screw and recheck to make sure dial has not slipped during tightening.

4. Turn power on. Allow 30 minute warm up before proceeding with phase alignment.

Detailed field alignment procedure.

5. Set Function Selector to "Fundamental".

6. Set Reference Selector to "External".

7. Set Range Selector to ".010".

8. Adjust voltage of signal source until approximately a full scale reading on Phase Angle Voltmeter is obtained (not less than .085).

9. Turn Reference Selector to "Adjust" and adjust reference level for "red line" value on the meter scale. Return Reference Selector to "External".

10. Set Phase Dial at 0^{o}.

11. Set Function Selector at 0^{o}.

12. Set Range Selector to ".003".

13. Adjust R71 (back panel control) for zero reading on meter.

14. Remove Capacitor and replace with R2, as noted in Table I above.

15. Set Function Selector to "Fundamental".

16. Set Range Selector to ".010".

17. Adjust voltage of signal source to give full scale reading on meter.

18. Turn reference adjust control full counter clockwise.

19. Set Reference Selector to "Adjust".

20. Adjust reference to "red line" value.

21. Set Reference Selector to "External".

22. Set Function Selector to "90^{o}" and phase dial to zero degrees.

23. Set Range Selector to ".003".

24. Adjust R48 ($+90^{o}$ ADJ) until Meter reads exactly zero.

25. Switch Function Selector to "0^{o}" and set phase dial to 90^{o}. Meter should read zero or very close to zero. If meter does not read zero, adjust R48 until offset from zero reading is the same for steps 24 and 25.

26. Set Range Switch to ".010". Set Function Selector to "180^{o}" and phase dial to 90^{o}.

27. Set Range Switch to ".003". Adjust R47 (-90^{o} adjust) until meter reads zero.

28. Set Function Selector to 270° and phase dial to 0°. Meter should read zero or very close to zero. If meter does not read zero, adjust R47 until offset from zero reading is the same for steps 27 and 28.

29. Repeat steps 5 through 13.

30. Repeat steps 14 through 28.

31. Repeat procedure of alignment (all steps) until no further adjustment of R71, R48, R49 will improve the zero reading of any of the steps.

32. Lock jam nuts on R47, R48 and R72.

NOTE: Misalignments from zero in terms of accuracy of ±90° points can be calculated. Smallest division on meter is equivalent to 0.38° at 3:1 overload, e.g., 1 volt input and range selector on 0.3. (See also "Phase Shifter Adjustment", page 3.4, Section III.)

FREQUENCY RESPONSE ADJUSTMENT

Equipment Required

1. Variable voltage frequency source capable of providing frequency of operation of instrument to 50,000 cps ±5% (e.g., Hewlett-Packard Model 200 CD).

2. VTVM having flat frequency response ±1db to 50 KC (e.g., Hewlett-Packard Model 400 D).

Procedure

1. Connect frequency source to signal input and monitor with VTVM.

2. Set frequency of source to normal operating frequency of Phase Angle Voltmeter.

3. Set Function Selector to "Total" position.

4. Set Range Selector to .001.

5. Adjust voltage of frequency source until Phase Angle Voltmeter meter reads 9. Note reading of monitor VTVM.

6. Increase frequency to 50 KC and set voltage of frequency source until Monitor VTVM reads the same as reading noted in step 5.

7. Adjust C33 (Trimmer Capacitor located on terminal board on

bottom of chassis) until Phase Angle Voltmeter meter reads 9 minus 1/2 smallest division (approximately 1% full scale).

8. Repeat steps 4 through 6 on .003, .3 and 1.0 ranges and record Phase Angle Voltmeter readings. If necessary, re-adjust C33 to give best overall tolerance on all ranges.

9. Acceptable performance will be an error of ±3% at 50 KC.

OVERLOAD ALARM ADJUSTMENT

This adjustment is usually required whenever the NE-51 is replaced.

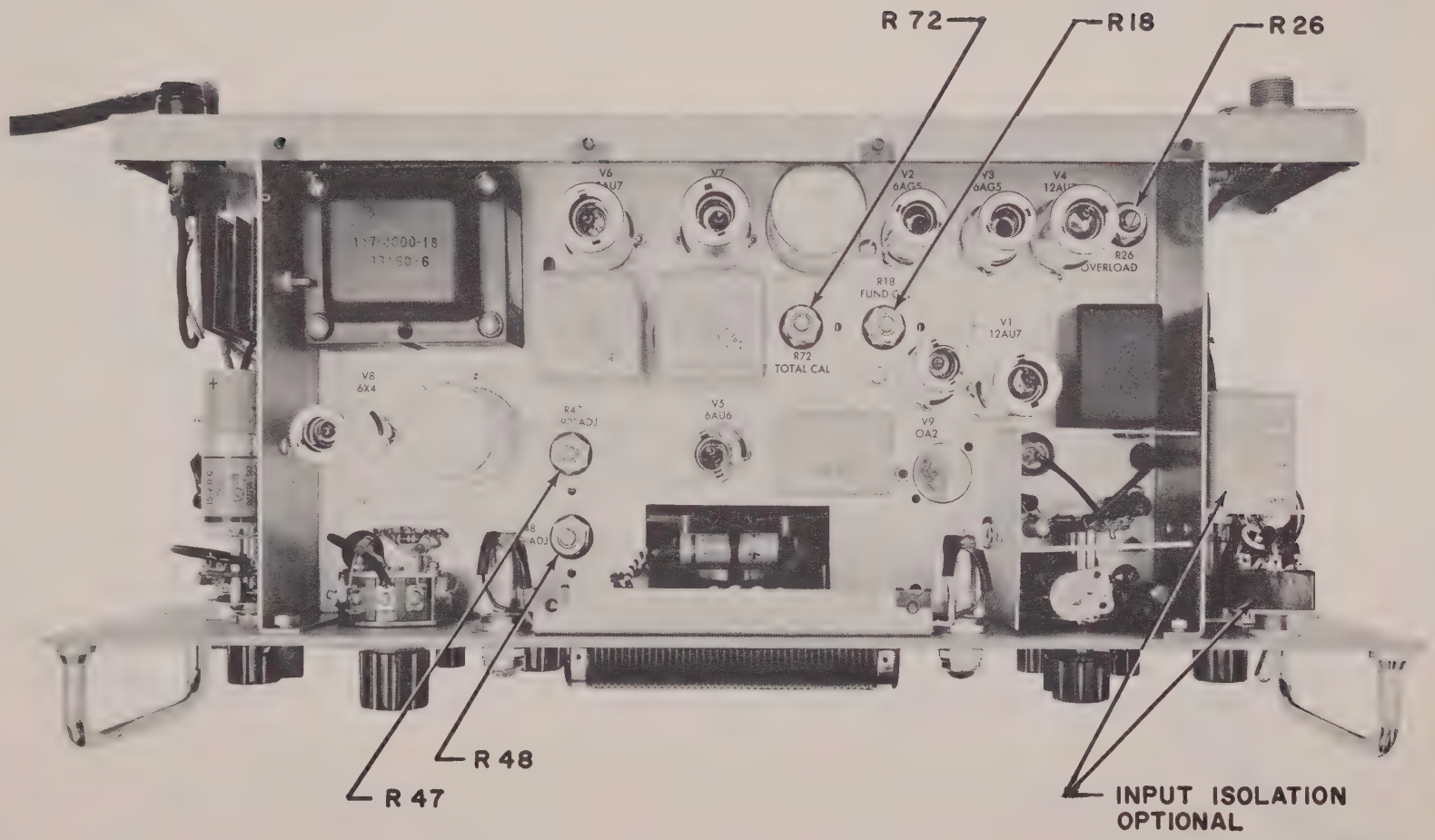
1. With an input of 0.5 volts applied to the instrument, switch the meter range switch to the 0.1 volt scale.

2. Adjust R26 until the overload lamp just lights.

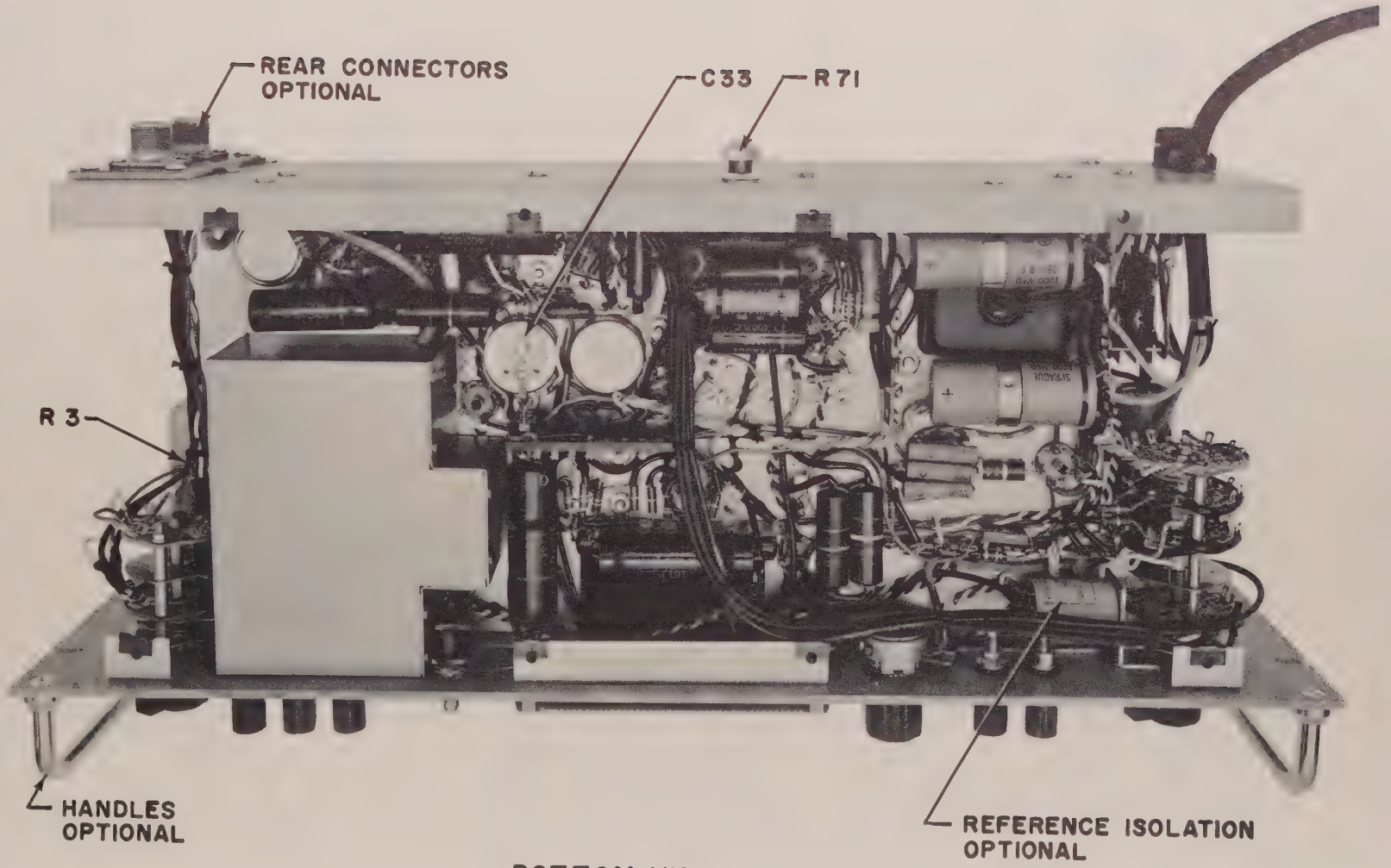
PHASE ANGLE DIAL POSITIONING

With the power off, use an ohmmeter to place the wiper of R51-1 exactly on the CCW tap point. The degrees dial should now be rotated so as to read 90°. Move ohmmeter to CW tap point and place wiper of Phase shift pot on this point. Dial should now read zero degrees. Position dial so as to achieve best compromise between the two taps. Fully tighten dial in this position. Check to make sure slippage has not occurred during tightening.

NOTE: THE DEGREE DIAL HAS A NON-LINEAR SCALE AND SHOULD NOT BE MOVED FOR ANY TEST REASON AFTER ONCE BEING SET.



TOP VIEW
FIG 6.1



BOTTOM VIEW
FIG 6.2

Replacement Parts List

Designation	Description	Source & Part No.*
C1	Capacitor, Paper, .047, 1000V	Sprague 160P473010
C2	Capacitor, Variable, 3-12 mmf	Erie TS-E
C3	Capacitor, Paper, .015 mf, 400V	
C4	Capacitor, Electrolytic, 20 mf,250V	
C5, C8	Capacitor,Metalized Paper,2.0 mf, 200V	Aerovox P82ZK10G
C6, C25, C30	Capacitor, Paper, .1 mf, 400V	
C7, A,B,C,D	Capacitor, Electrolytic, 4X10 mf, 450V	
C9	See Frequency Table on Schematic	
C10	Capacitor, Electrolytic, 500mf,6V	
C11	Capacitor, Paper, .47 mf, 400V	
C12	Capacitor, Paper, .22 mf, 400 V	
C13,C17,C18	Capacitor, Electrolytic, 50 mf,6V	
C15	Capacitor, Paper, .15 mf, 200V	
C16	Capacitor, Variable, 7-45 mmf	Erie TS-E
**C20	Capacitor, Mica, 39 mmf, 500V	
C21, C38	Capacitor, Paper, .047 mf,200V	
C22, C37	Capacitor, Paper, 1.0 mf, 200V	
C23	See Frequency Table on Schematic	
C24	Capacitor, Paper, .033 mf, 400V	
C26, C29	Capacitor, Electrolytic, 5.0mf,50V	
C27, C28	Capacitor, Paper, .047 mf, 400V	
C31, C32	See Frequency Table on Schematic	

* Part number given only when no commercial equivalents in size or function are available.

** Used in 60 and 400 cycle units only.

Replacement Parts List (Cont'd.)

Designation	Description	Source & Part No.*
C33, A, B, C	Capacitor, Electrolytic, 3X20 mf, 450V	
C34,C35,C36	Capacitor, Electrolytic, 1000mf, 15V	
C39	See Frequency Table on Schematic	
R3	Resistor, Variable, WW, 10K, 2W	
R4, R53	Resistor, Comp., 470 ohms, 1/2W, 10%	
R5, R54	Resistor, Comp.,2.2Meg, 1/2W,5%	
R6,R17,R25, R55	Resistor, Comp.,1.2K,1/2W,10%	
R7,R35,R38, R56,R76,R87	Resistor, Comp.,47K,1/2W, 10%	
R8, R22	Resistor, Comp.,5.1K,1/2W, 10%	
R16,R29,R30	Resistor, Comp.,1Meg, 1/2W,10%	
R18, R72	Resistor, Variable, WW,50 ohms, 2W	
R19,R28,R32, R57	Resistor, Comp.,10K,1/2W,10%	
R20,R50,R61, R62,R65,R67	Resistor, Comp., 470K, 1/2W, 10%	
R21	Resistor, Comp., 51K, 1/2W, 5%	
R23, R31	Resistor, Comp.,680K,1/2W,10%	
R24,R33,R83	Resistor, Comp.,220K,1/2W,10%	
R26	Resistor, Variable, 50K, 2W	
R27	Resistor, Fixed,WW,12 ohms,3W,5%	Dale RS-2
R35	Resistor, Fixed,WW,7.5 ohms,3W,5%	Dale RS-2

* Part number given only when no commercial equivalents in size or function are available.

Replacement Parts List (Cont'd.)

Designation	Description	Source & Part No.*
R36	Resistor, Comp., 22 ohms,1/2W,5%	
R37	Resistor, Comp., 75K, 1/2W, 10%	
R39,R40,R41, R42	Resistor, Comp., 2.2K, 1/2W, 5%	
+R44, R46	Resistor, Comp., 47K, 1/2W, 10%	
+R45	Resistor, Comp., 15K, 1/2W, 10%	
R47, R48	Resistor, Variable, WW, 4K, 2W	
R49,R60,R66	Resistor, Comp., 820 Ohms, 1/2W,10%	
R51	Resistor, Variable, WW, 50K,Tapped	NAI B-117-2.000-39
R52	Resistor, Variable, Comp.,100K, 2W	Allen Bradley JA2N048P104AA
R58,R63,R68	Resistor, Comp., 150K,1/2W, 10%	
R64,R69	Resistor, Comp., 4.7K, 1/2W,10%	
***R70,R82	Resistor, Comp., 4.3 ohms, 1/2W,10%	
R71	Resistor, Variable, WW, 50K, 2W	
R73,R74	Resistor, Comp., 1.5K, 1/2W, 10%	
R75, R78	Resistor, Dist.Carb., 39K, 1/2W,1%	
R79,R85	Resistor, Power, WW, 15K,5W, 5%	
R80	Resistor, Comp.,470 ohms,2W,10%	
R81	Resistor, Power, WW, 7K, 5W, 5%	
R84	Resistor, Comp., 100K, 1/2W, 10%	
R86	Resistor, Comp., 27K, 2W, 10%	

* Part number given only when no commercial equivalents in size or function are available.
** Used only in 60 and 400 cycle units.
*** Nominal value. Value adjusted at factory.
\+ Used only in units having Reference Isolation Circuit.

Replacement Parts List (Cont'd.)

Designation	Description	Source & Part No.*
V1, V4, V6	12AU7	
V2, V3	6AG5	
V5	6AU6	
V7	12AX7	
V8	6X4	
V9	OA2	
CR1,CR2,CR3, CR4	See Frequency Table on Schematic	
CR5	Selenium Rectifier	Radio Receptor D16N1B1E1G
M1	Meter	NAI 800899
XF1	Fuseholder	Littelfuse 342001
F1	Fuse, 1 Amp	Littelfuse 312001
I1	Pilot Light, 6.3V	
I2	Overload Lamp NE-51	
XI1	Lampholder, Pilot	Dialco 810B-112
XI2	Lampholder, Overload	Dialco 810B-117
S4	Function Switch Ass'y.	NAI B-500007
S3	Range Switch Ass'y.	NAI B-500101
S2	Reference Switch Ass'y.	NAI B-500005
S1	Switch, Toggle (SPST)	C.H. 8280-K15
T1	Transformer, Power	NAI C117-2.000-18
T2,T3,T4,T5	See Frequency Table on Schematic	

* Part number given only when no commercial equivalents in size or function are available.

Replacement Parts List (Cont'd.)

Designation	Description	Source & Part No.*
	Knob, Bar	Acton Labs KN-1P
	Knob, Reference Adjust	Acton Labs KN-1
	Line Cord	
	Phase Angle Dial Sub-Ass'y.	NAI 500104
	Binding Post, Red	Grayhill 29-1R
	Binding Post, Black	Grayhill 29-1B
	Terminal Mount	Grayhill 29B11-1

* Part number given only when no commercial equivalents in size or function are available.

SECTION VII

WARRANTY

North Atlantic Industries, Inc. hereby warrants that this instrument is free from defects in material and workmanship. Liability under this warranty is limited to servicing, calibrating and replacing any defective parts with the exception of electron tubes and fuses, if, within ninety days after shipment the original purchaser notifies North Atlantic Industries, Inc. that the instrument is defective and has not been damaged in shipment. Notification should give full details of the defect, including model and serial number of the instrument. Purchaser shall then await servicing or shipping instructions from North Atlantic Industries, Inc.

Upon receipt (transportation charges prepaid) of any returned instrument, North Atlantic Industries, Inc. shall, during the warranty period, repair the instrument free of charge provided that the instrument is found to be defective and there is no evidence that it has been operated beyond its design range, has been improperly tested, or has been opened, disassembled, adjusted, modified, dropped or tampered with in any way.

In the event that repairs are necessary which are not covered by the warranty, an estimate of costs to be incurred will be submitted before any work other than determining the defect is undertaken.

NOTE

This instrument has been carefully checked and packaged. The carrier is responsible for loss, damage, or delay in shipment, and if upon receipt, the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be made by the carrier claim agent and forwarded to North Atlantic Industries, Inc. We will advise disposition and arrange for repair or replacement of the instrument.

WARRANTY

North Atlantic Industries, Inc. hereby warrants that this instrument is free from defects in material and workmanship. Liability under this warranty is limited to servicing, calibrating and replacing any defective parts with the exception of electron tubes and fuses if, within one (1) year after shipment the original purchaser notifies North Atlantic Industries, Inc. that the instrument is defective. Notification to the Sales Order Department of North Atlantic Industries, Inc. should give full details of the defect, including model and serial number of the instrument. Purchaser shall then await servicing or shipping instructions from North Atlantic Industries, Inc.

North Atlantic Industries, Inc. will repair and pay transportation charges of any instrument that is found defective during the period of our warranty. This shall be subject to the condition that there is no evidence that the instrument has been operated beyond its design range, has been improperly tested, or has been opened, disassembled, modified, dropped or tampered with in any way.

In the event that repairs are necessary which are not covered by the warranty, an estimate of costs to be incurred will be submitted for written approval before any work other than determining the defect is undertaken.

In-warranty repairs will be returned, transportation paid, by the original methods of shipment. Repairs not covered by the warranty will be returned in accordance with purchaser's instructions submitted with approval of repair charges.

North Atlantic Industries, Inc. shall not be liable for damage or injury to persons or property resulting from the operation of the instrument.

NOTE

This instrument has been carefully checked and packaged prior to shipment. Any loss, damage, or delay in shipment should be reported to the carrier. Further, if upon receipt the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier claim agent and forwarded to North Atlantic Industries, Inc., who will advise disposition and arrange for repair or replacement of the instrument.

In line with North Atlantic Industries' policy of prompt service to all customers, every effort will be made to repair and return any instrument as rapidly as possible.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration or setting up of instrument.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter and a power factor meter.

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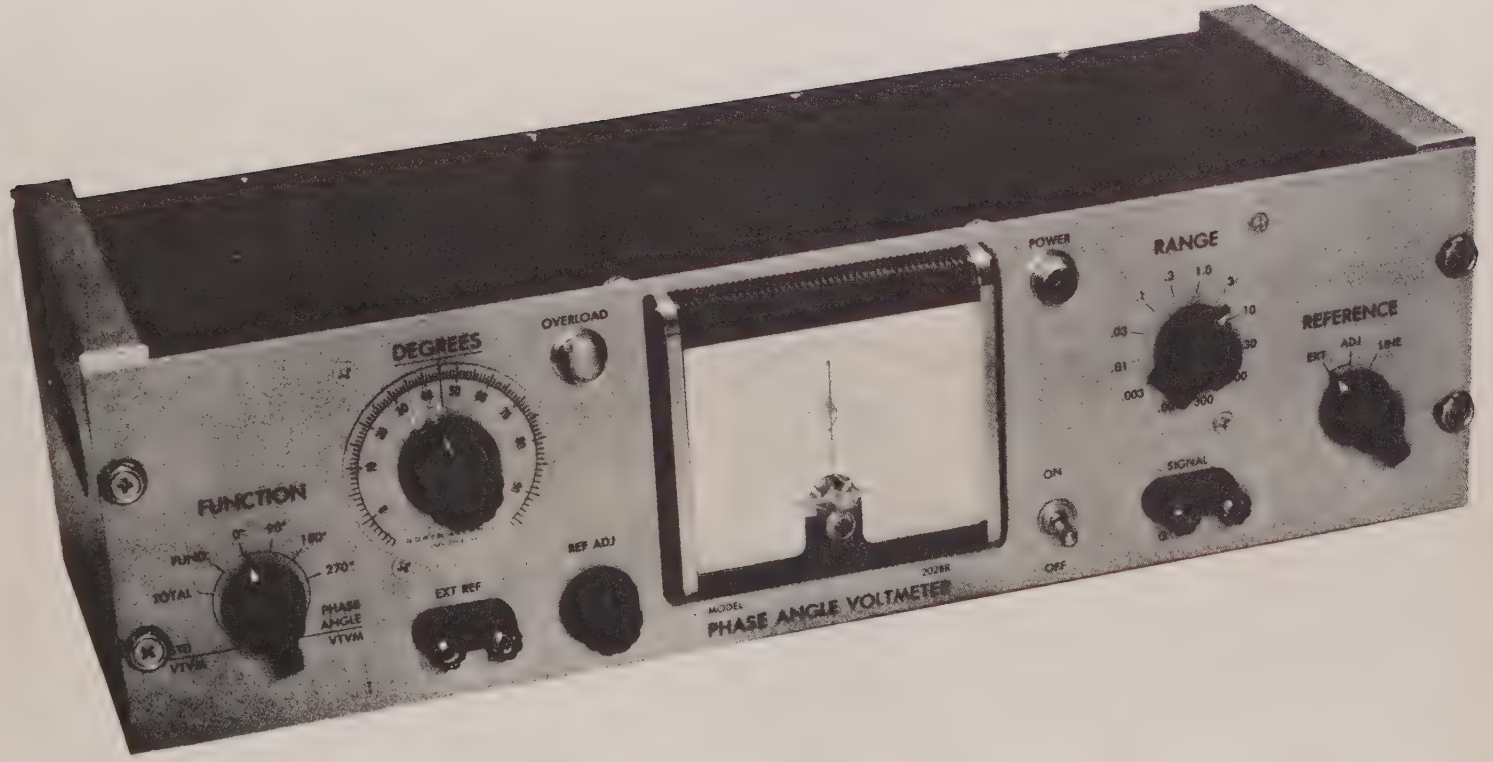


PHASE ANGLE VOLTMETER

TABLE OF CONTENTS

		PAGE
I	Introduction	1
II	General Notes on Grounding Techniques	2
III	Phase Characteristic	4
	1. Response to Harmonics	
	2. Accurate Phase Measurements	
IV	Phase Angle Measurement Using Phase Shifter	9
V	Measurement of In-Phase and Quadrature Components	10
VI	Measurement of Power Factor and Impedance Angle	10
VII	Measurement of Impedance	11
VIII	Applications	12
	1. Precision Ratiometer	12
	2. Transducer Nulling	13
	3. Synchro Bridge Null Detector	14
	4. Magnetic Amplifier and Thyratron Circuit Alignment	15
	5. Carrier Circuits and Amplifier	15
	6. Transformation Ratio	16
	7. Small Angle Measurements	17

I-INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instruments ability to measure the two basic characteristics of any signal, namely magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure 1.

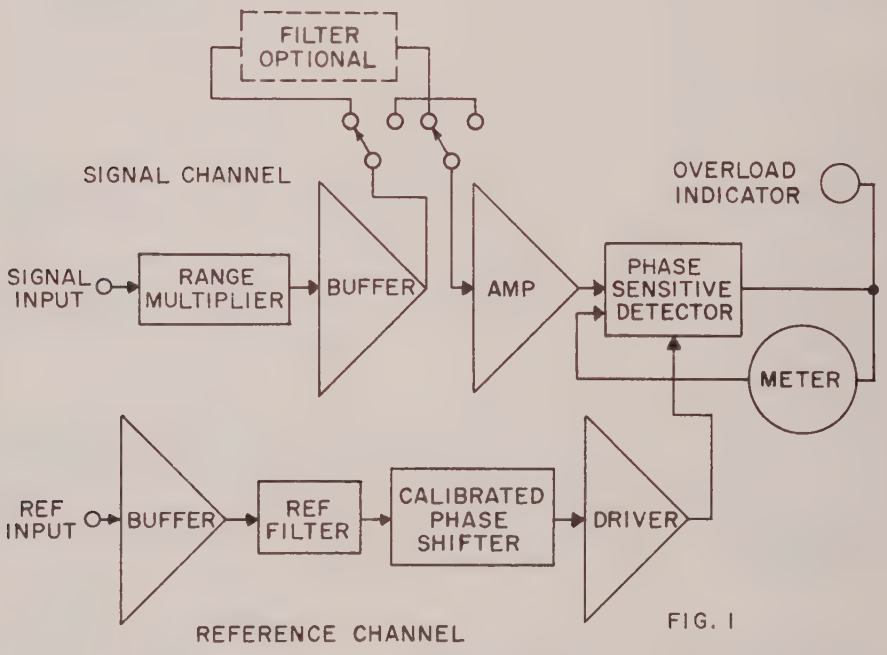


FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an a.c. signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures 5 and 6.

The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II-GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

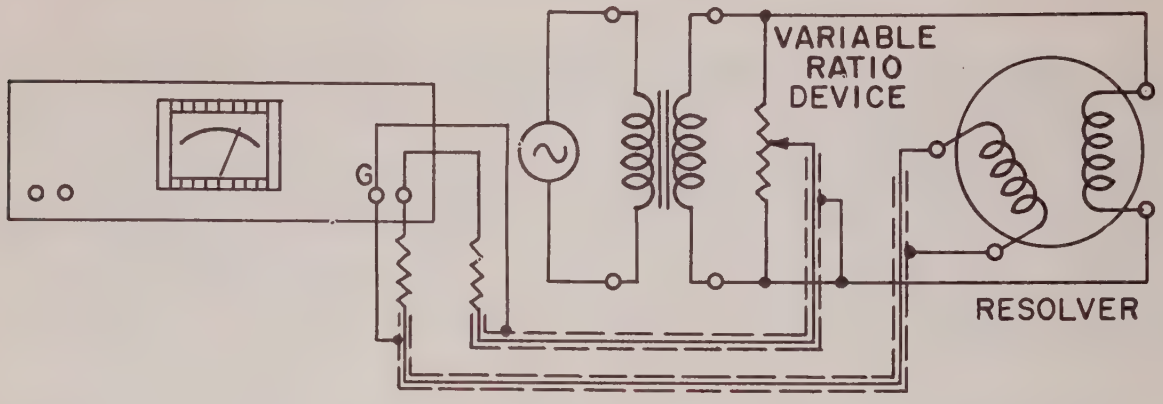
(a) Internal noise
(b) Electrostatic pickup
(c) Inductive pickup
(d) Common Ground Runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

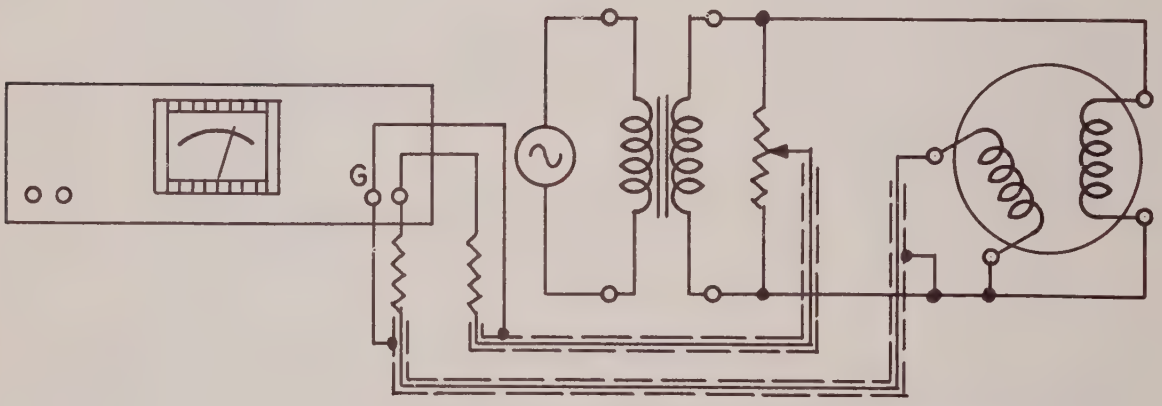
Electrostatic pickup, frequently a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads, one of which is at ground potential. Care must be taken however to avoid loading the signal source by the by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pickup and possibly for that reason methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

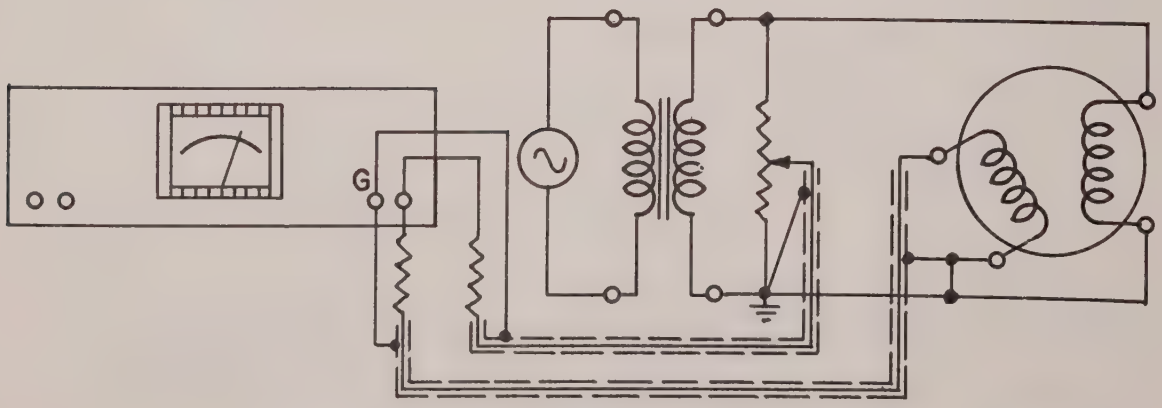
Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that portion of a circuit where a measurement is being made. Fig. 2 shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure 2A is the most advantageous arrangement and is not at all critical to lead runs. Figures 2B and 2C both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure 2 can exist due to chassis contact, line cord ground and reference grounds. All must be considered when setting up the measuring system.



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

Common Ground Runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure 3 is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure 3 also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

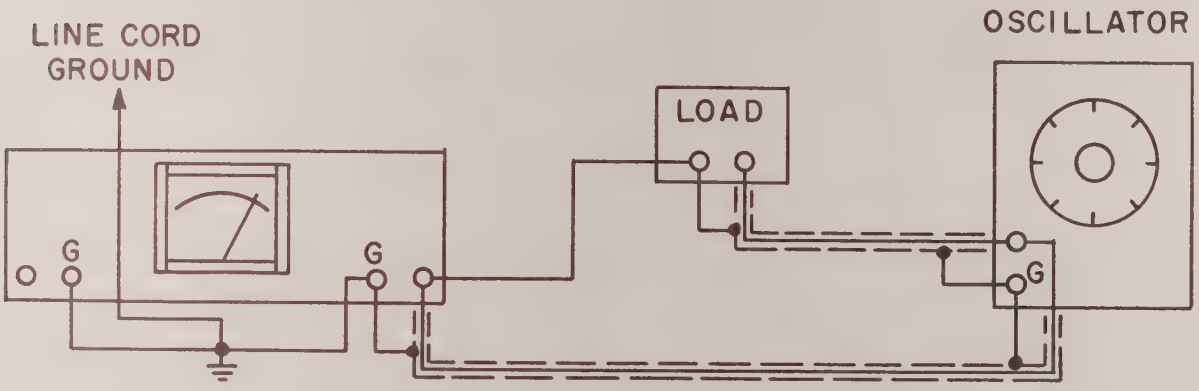


FIG. 3

III-PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter

E_{rms} = rms value of the input sine wave

θ = angle between the reference and signal input (phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

$$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55 db down. Table I shows typical measured responses. The values shown with filters actually are the sum of the column I data and the filter characteristic.

TABLE I

	RESPONSE SIGNAL	
	No Signal Filter	With Signal Filter
FUND (400 cps)	0 db	0 db
2nd Har	-55 db	> -55 db
3rd Har	-9.5 db	> -55 db
4th Har	-55 db	> -55 db
5th Har	-14 db	> -55 db

Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the set-up shown in Figure 4. The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement then will be a voltage which can be directly translated into degrees using the curves of Figures 5 and 6.

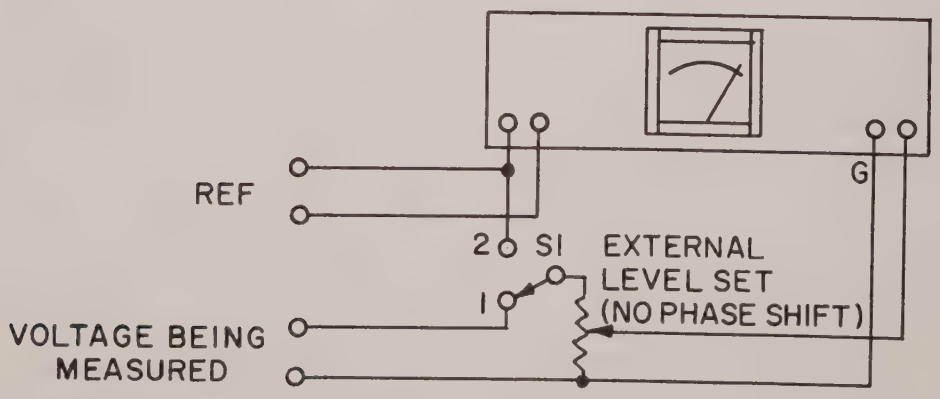


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (Note: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.

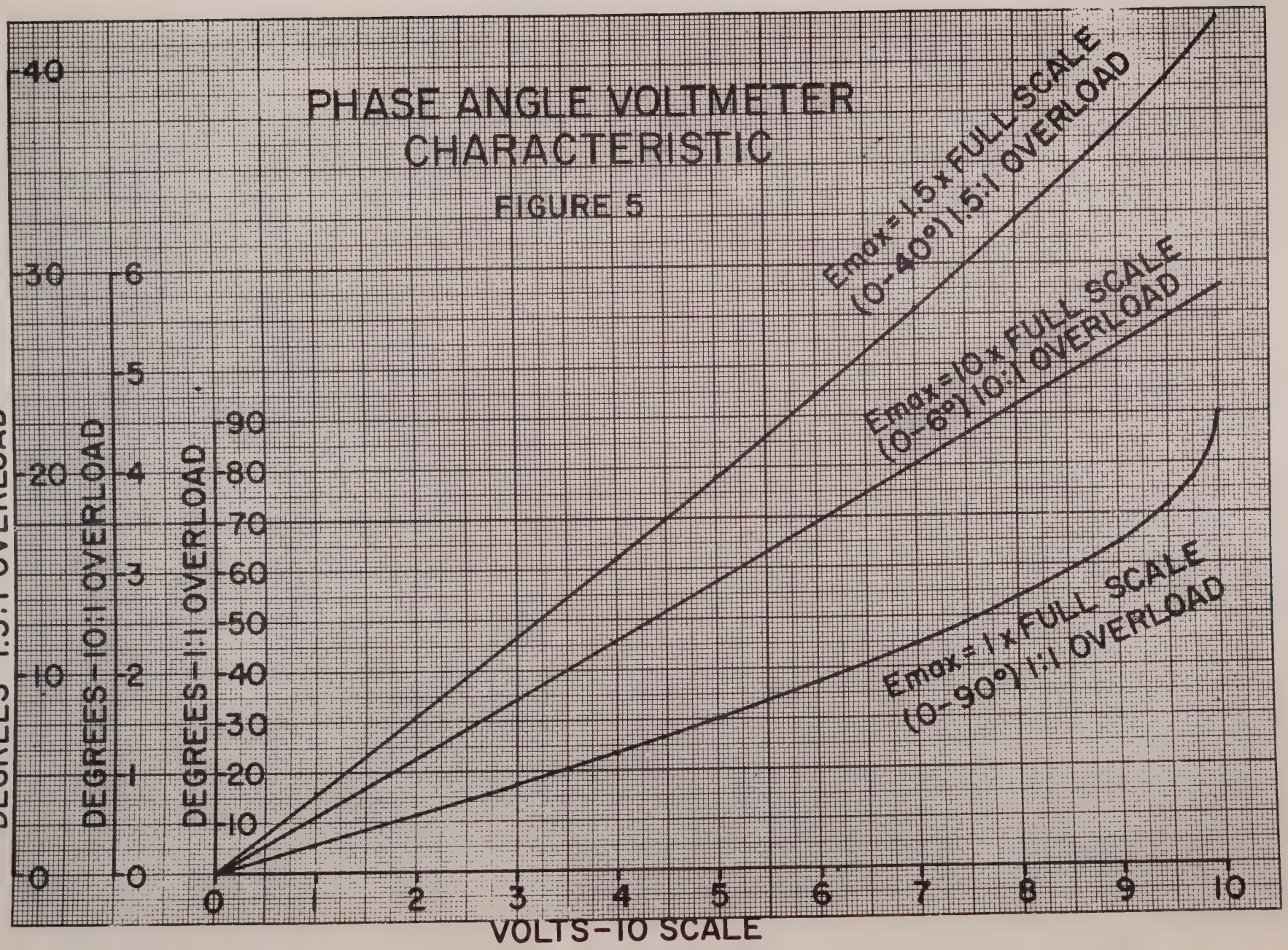
3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection. Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the $\theta = 0$ deg. point or quadrature null point. NOTE: FOR MAXIMUM ACCURACY THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the $\theta = 90$ deg. point. (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure 5 or 6 to read degrees.

Any full scale range in degrees can be used even down to -6°-0-$+6^{\circ}$ depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4 deg.-0- +17.4 deg. Table II summarizes typical set-ups and Figures 5 and 6 show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously this condition is a function of reference level and for that reason a level of twice the red line value is recommended when using this techique.


PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90

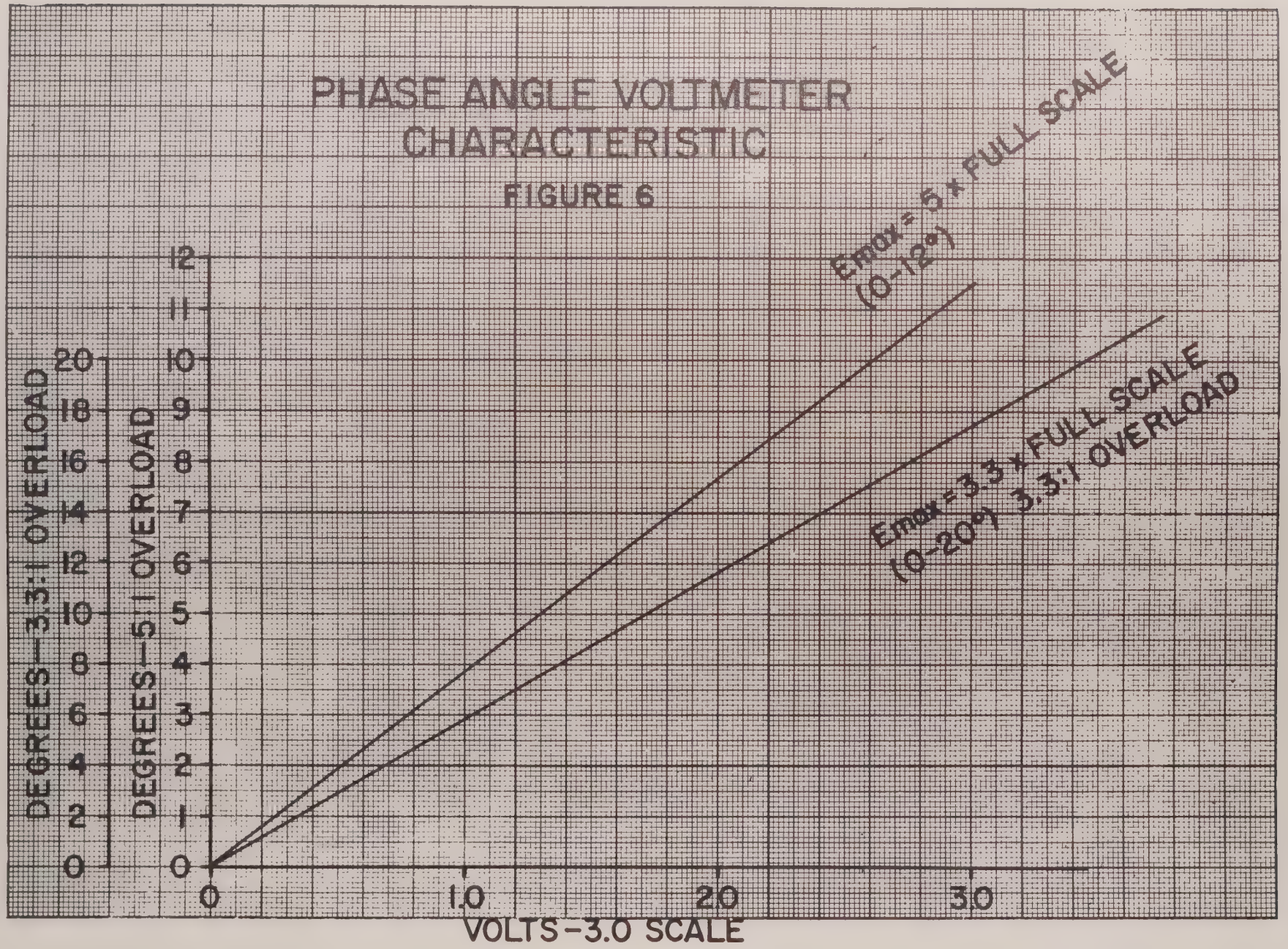

PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 6 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES—3.3:1 OVERLOAD
DEGREES—5:1 OVERLOAD
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS—3.0 SCALE

TABLE II

Max. Voltage	Scale for meas. deg.	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	∠ 90	2.7 deg.	5
1.0	.3	3.3:1	∠ 19.5	0.6	6
1.0	.1	10:1*	∠ 5.7	.2*	5
1.5	1.0	1.5:1	∠ 41.8	1.3	5
1.5	.3	5:1	∠ 11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV-PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built in calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V-MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

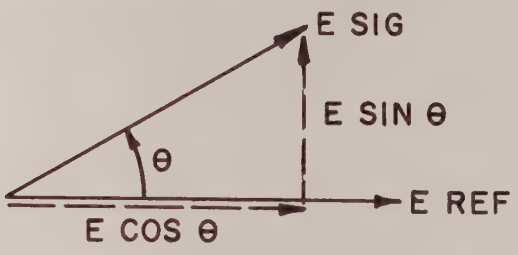


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure 7 as:

In-phase component = E cos θ

Quadrature Component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI-MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This measurement is conveniently accomplished by means of the set-up shown in Figure 8. The angle is measured as previously discussed.

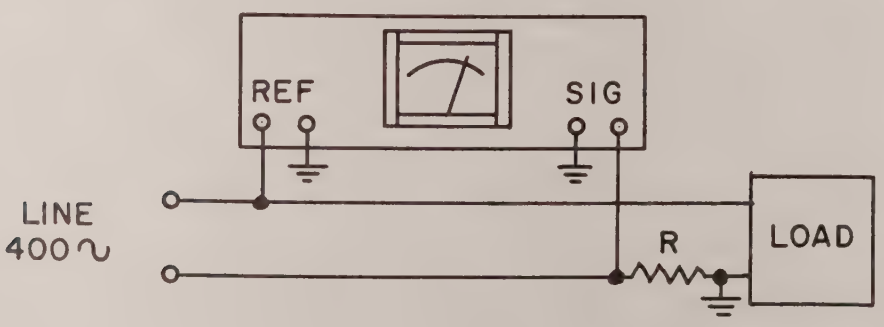


FIG. 8

VII-IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure 9 illustrates the manner in which the measurements can be made.

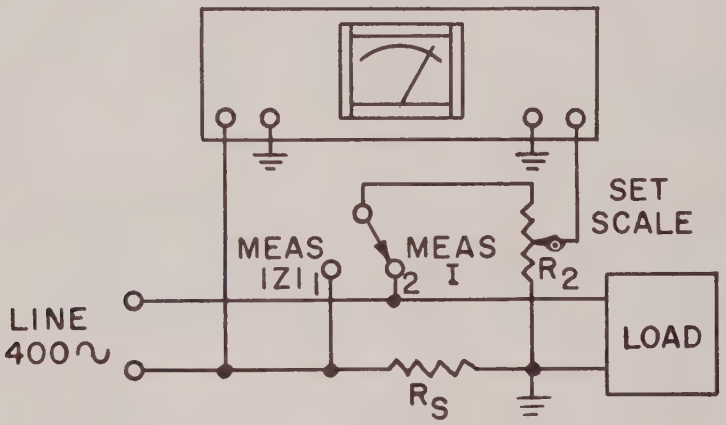


FIG. 9

Using Table III as a guide, a precision ($\leq$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale volts on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE

Load Impedance = 470K

Rs = 1K

E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1 Volt Equals	Current Factor
10K	10K	1/volts
1K	1K	"
100 ohms	100 ohms	"
10 ohms	10 ohms	"
1 ohm	1 ohm	"

Measurement of A.C. Resistance and Reactance

By using the circuit of Figure 9 the real and imaginary components of the impedance can also be measured directly by using the current as a referency and measuring the in-phase and quadrature components of the signal measured with the switch in position 2. The in-phase component will be the A.C. Resistance and the quadrature component will be the reactance with the sign determined as positive for a right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII-APPLICATIONS

Precision Ratiometer

In many analogue computer systems the process of multiplication, division, addition and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure 10 permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

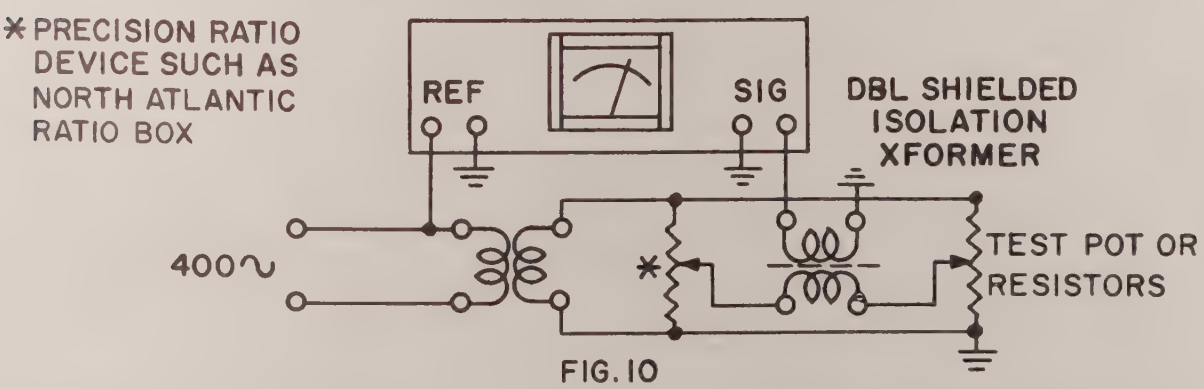


FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance transformer such as a North Atlantic T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

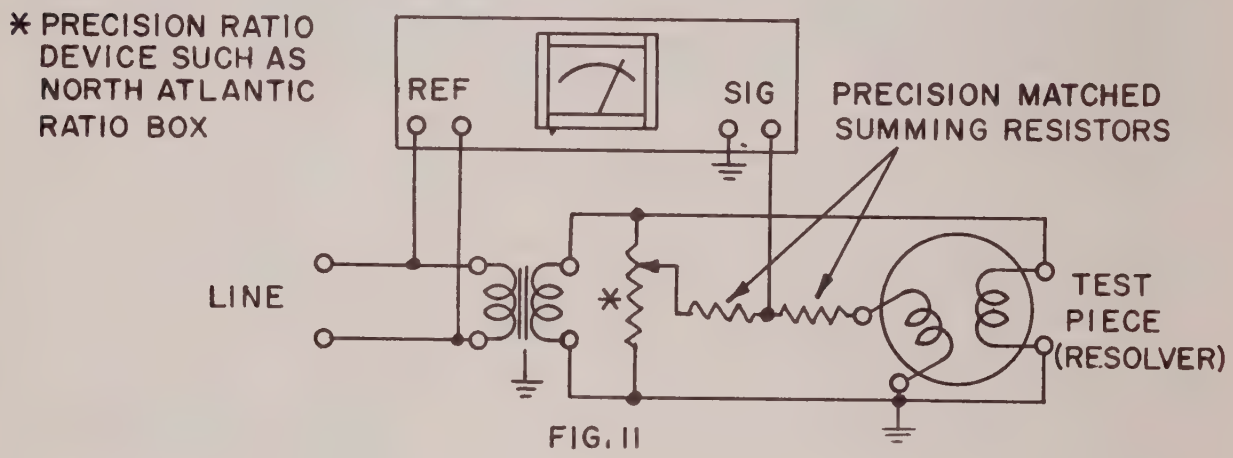


FIG. 11

Transducer Nulling

Applications involving transducers such as differential transformers or E-Coil pickoffs are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure 12 shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

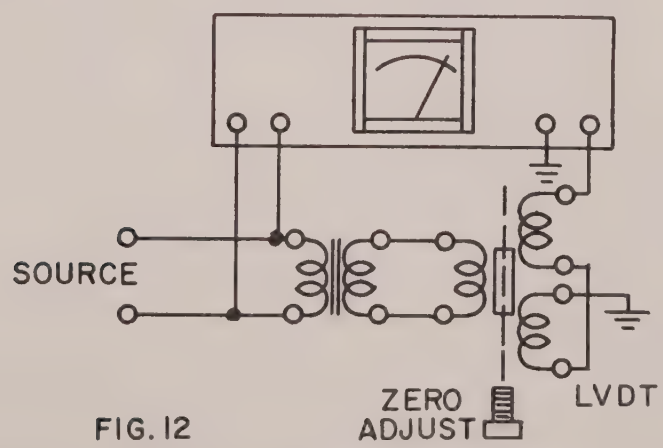


FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure 13 is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible precision nulls unobtainable by conventional instrumentation.

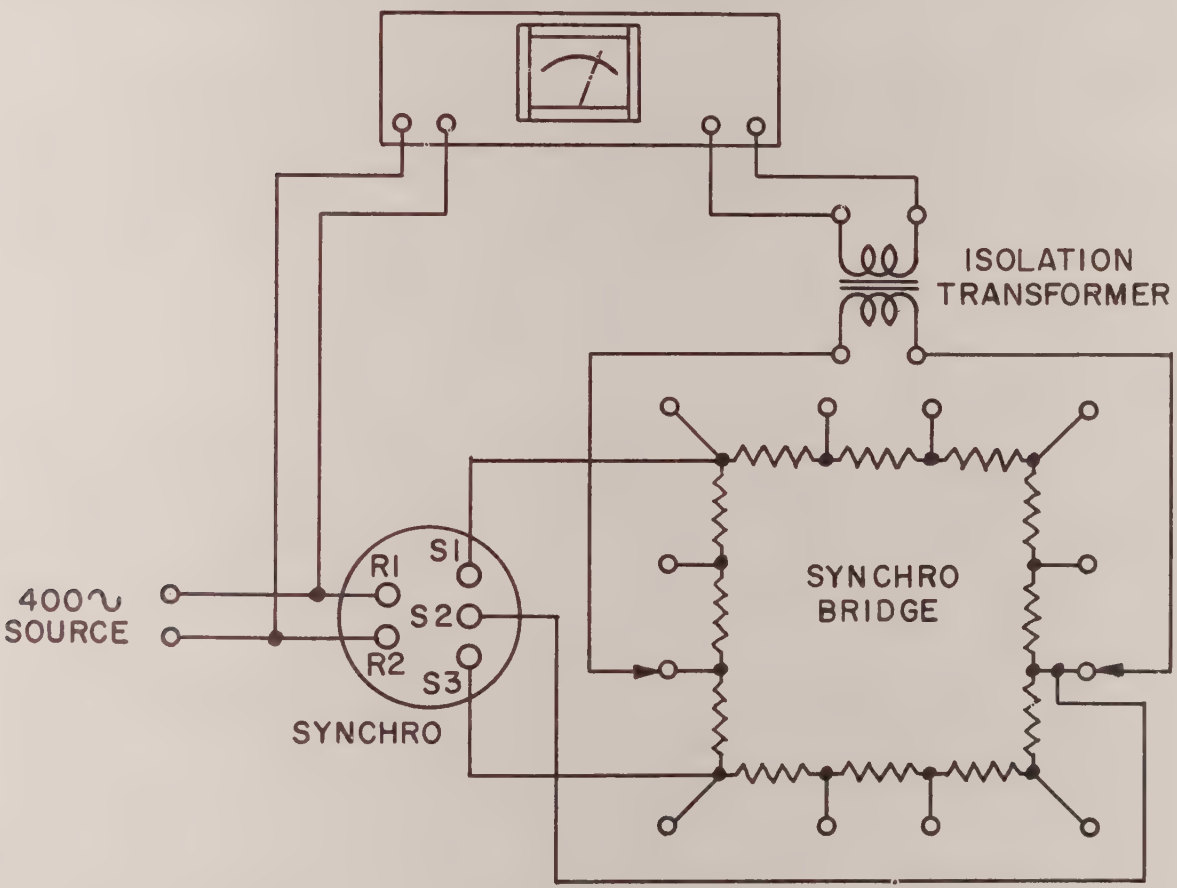


FIG. 13

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped wave forms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure 14, the task of alignment for maximum torque or output is straight forward since the meter reading is equivalent to motor output.

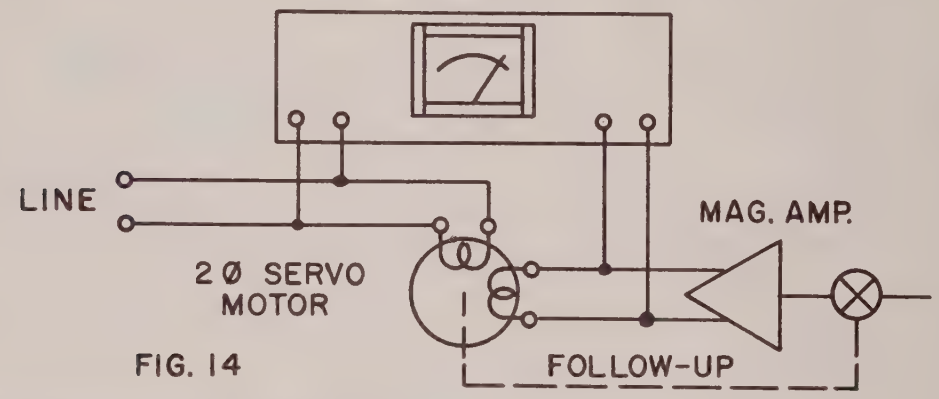


FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc. must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure 15 is a test set-up used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

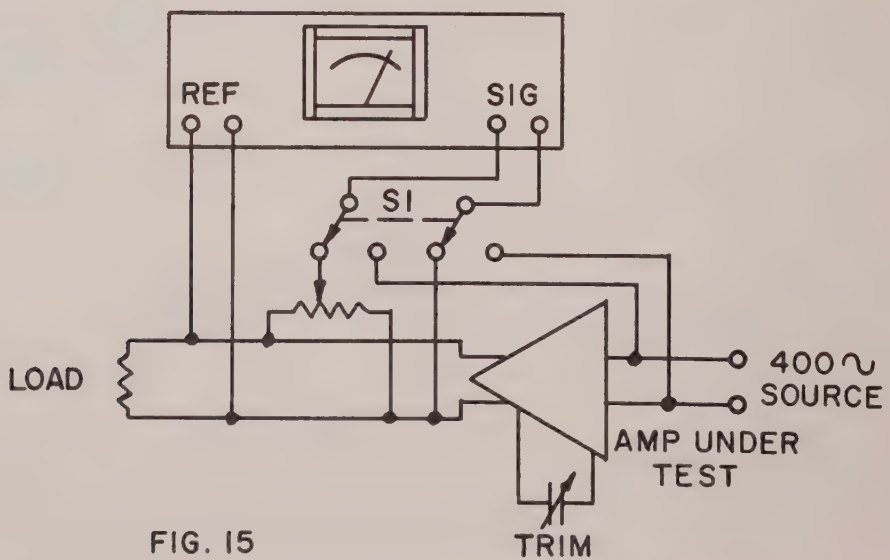


FIG. 15

TRANSFORMATION RATIO

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure 16 (a) and 16 (b).

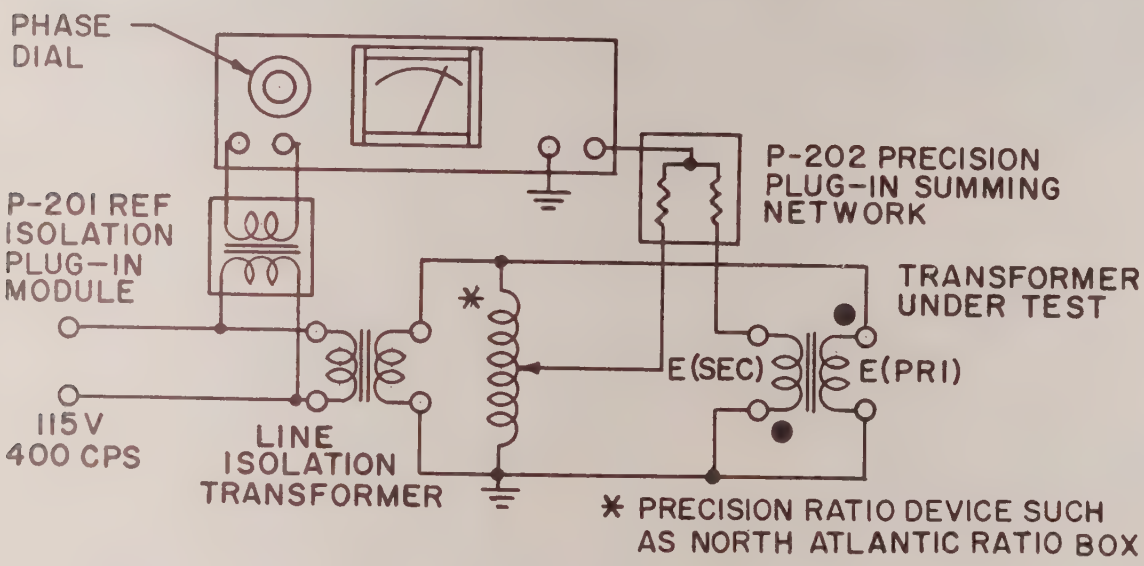


FIGURE 16(a)

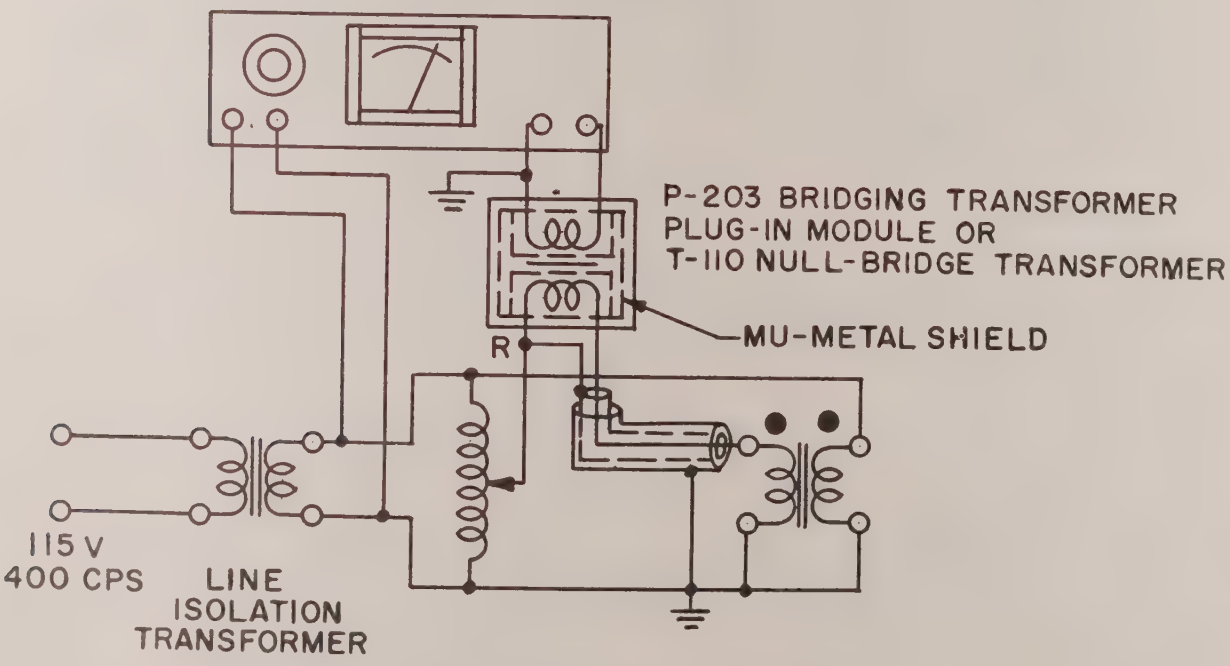


FIGURE 16(b)

I. SUMMING NETWORK TECHNIQUE

In Figure 16 (a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test set up a line isolation transformer is utilized so as to avoid grounding one side of the line. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure 16 (a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure 16 (b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common mode rejection and low input capacitance would suffice.

Measurement errors in Figure 16 (b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the figure.

Common mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each set up must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both set-ups require that the phase dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc.. This is conveniently done by stepping the ratio device and adjusting the phase dial to produce zero output when the function selector is in the 90° position. Operation will then be correct when the function selector is returned to the 0° position.

Small Angle Measurements

Small angle measurements to better than .01° can also be made using the set ups of Figure 16. The process consists of making the in-phase null, described in the foregoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{ E sec }|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

Measured quadrature = 30.0 millivolts

Secondary voltage = 30 volts

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$

SECTION III

RATIO TCX

RATIO BOX

SPECIFICATIONS

Ratio Range	0.000000 to ±1.111110
Accuracy @ 400~ (Terminal Linearity)	2.0 ppm
Frequency Range	50~ to 3KC
Voltage Rating (f in cps)	.35f to 350V max.
Input Impedance @400~	>10K
Nominal Output Resistance	10 ohms
Resolution	5 decades + potentiometer (0.3ppm)
Phase Shift	Less than 1 min.
Switches	heavy duty

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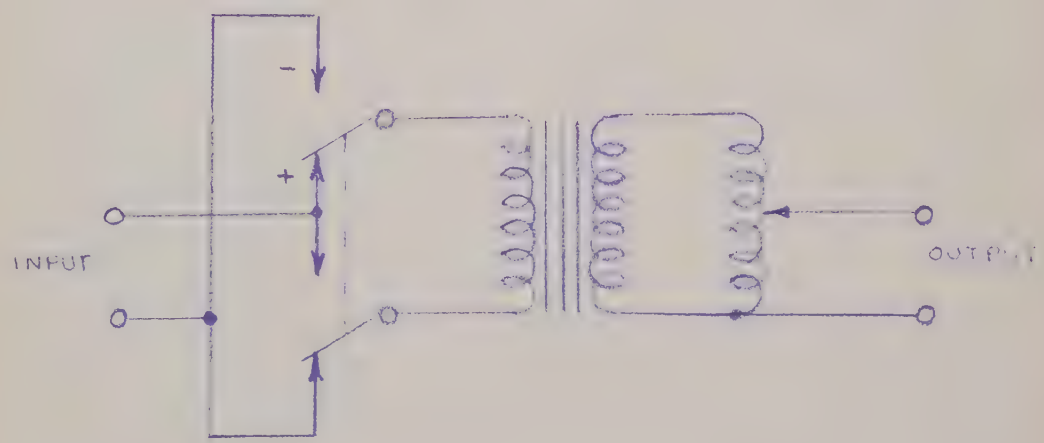
GENERAL DESCRIPTION:

The Ratio Box section of the CVR incorporates the features of the high accuracy of the standard RB-504 and the North Atlantic Model T-120 Precision Inversion Transformer. This combination provides a complete range of ratios from -1.111110 to +1.111110, as well as signal isolation.

OPERATION:

1. Place the EXC-PAV-CVR switch in the PAV position.
2. Connect input to the EXC OUT (E) terminals (See Specifications for maximum input voltage).
3. Select desired input (+,-).
4. Connect low side of output to ground.
5. Read output from "OUT" and "COM" terminals.



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APPLICATIONS:

The Ratio Box Section is ideal for the precision calibration of resolvers and synchros where a minimum loading, high accuracy, and low phase shift are essential. They also eliminate the need for re-arranging the test setup or providing additional inversion switching within the test set. In these and other applications, use of the ratio boxes in conjunction with North Atlantic's Phase Angle Voltmeter* permits rapid, direct reading of nulls, phase shift angle, and quadrature voltage.

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SUMMING NETWORK TECHNIQUE

In Figure (3) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors-available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test set up, a line isolation transformer is utilized so as to avoid grounding one side of the line. For illustrative purposes, the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure (3), care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure (4) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common mode rejection and low input capacitance would suffice.

Measurement errors in Figure (4) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the figure.

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Common mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer, and the relative values of these impedances. Each set up must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both set-ups require that the phase dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc. This is conveniently done by stepping the ratio device and adjusting the phase dial to produce zero output when the function selector is in the 90^{o} position. Operation will then be correct when the function selector is returned to the 0^{o} position.

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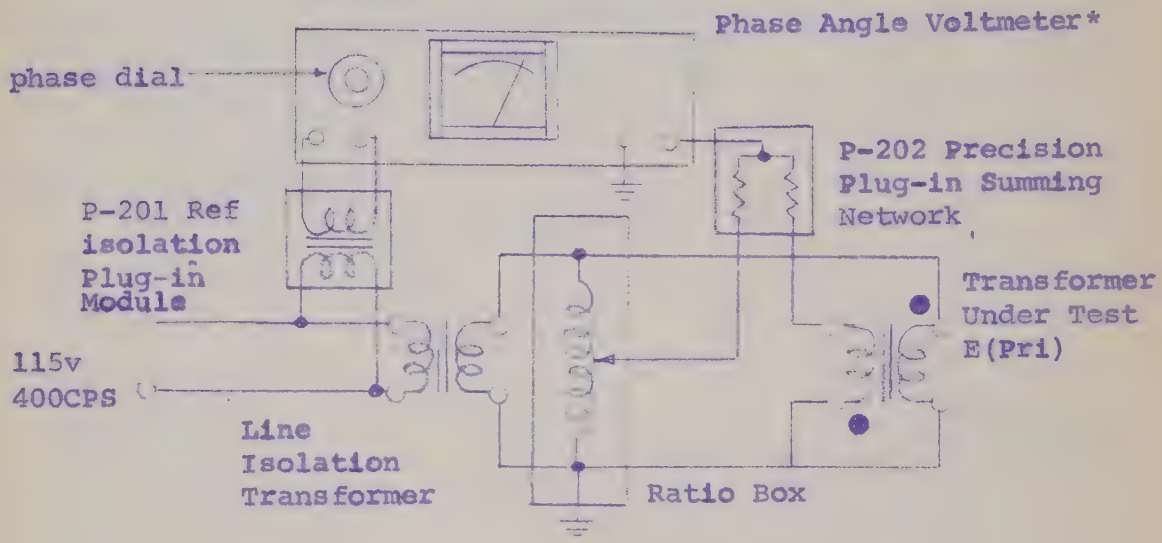

Fig. 3 Parallel Summing

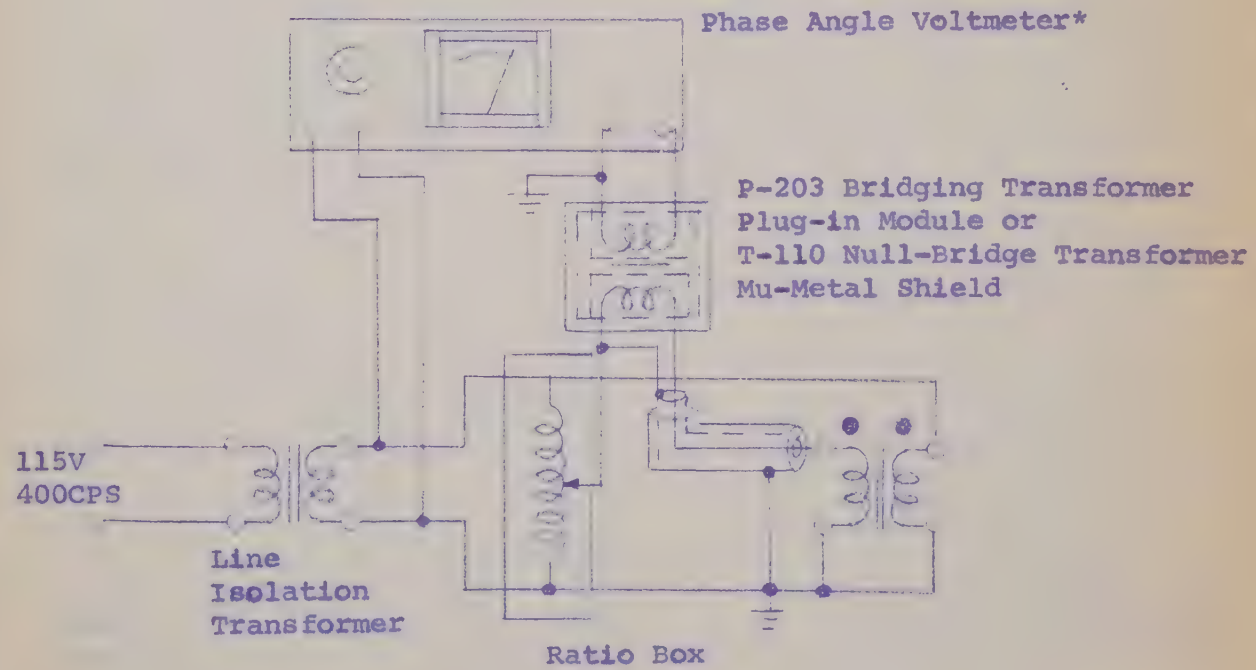

Fig. 4 Series Summing

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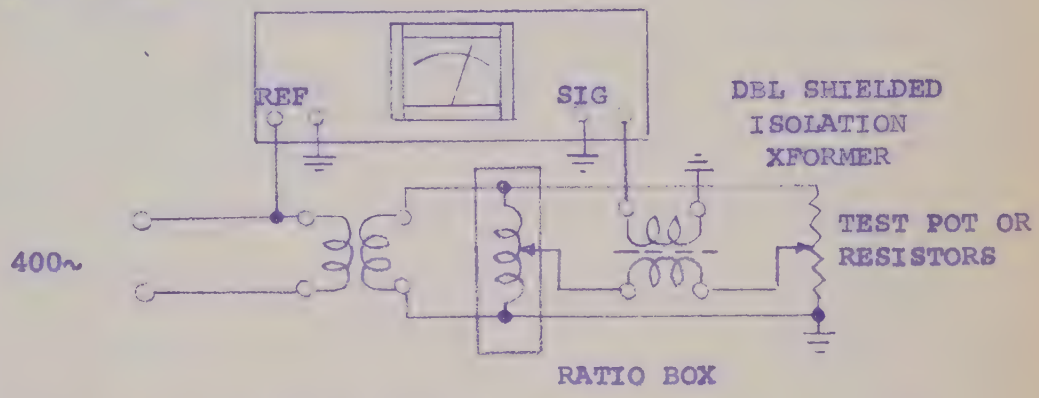
PRECISION RATIOMETER

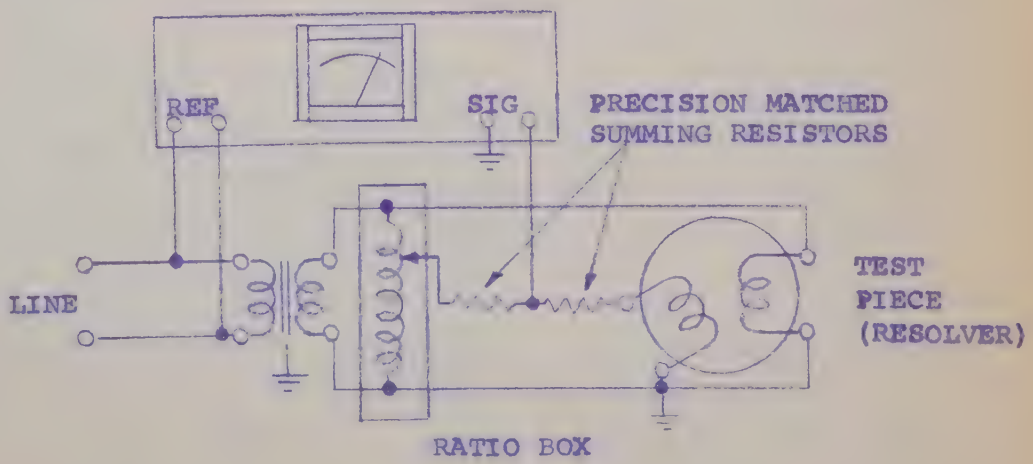
In many analogue computer systems the process of multiplication, division, addition, and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element, Ordinary nulling systems, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure 5 permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

*Phase Angle Voltmeter



Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance transformer such as a North Atlantic T-110 should be used. An alternate arrangement would be the circuit of Figure 6, which uses a summing network.

*Phase Angle Voltmeter



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REPLACEMENT PARTS LIST

NAI PART NO.	DESCRIPTION	RB-503T	RB-504T
D-500063	Switch, 1st Decade		1
C-500064	Switch, 2nd and 3rd Decades		2
C-500065	Switch, 4th and 5th Decades		2
C-500066	Switch, 4th and 5th Decades	2	
C-500067	Switch, 1st Decade	1	
C-500068	Switch, 2nd and 3rd Decades	2	
B-500023-1	Dial, Assembly, 0 thru 10 -graduated	1	1
B-500023-2	Dial, Assembly, 0 thru 10 -ungraduated	5	4
B-500023-3	Dial, Assembly, -(Red) thru 10		1
C-200380	Window	1	1
B-800568	Rheostat (last digit)	1	1
	Fuse (output) 1 amp. Littlefuse #312005 or equal	1	1
	Fuse (input) 5 amp. Littelfuse #312005 or equal	1	
C-200215	Ratio Transformer, 1st Decade		1
C-200214	Ratio Transformer, 2nd Decade		1
C-200208	Ratio Transformer, 3rd Decade		1
C-200210	Ratio Transformer, 4th Decade		1
C-200211	Ratio Transformer, 5th Decade		1
C-200216	Ratio Transformer, 1st Decade	1	
C-200213	Ratio Transformer, 2nd Decade	1	

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REPLACEMENT PARTS LIST (cont'd.)

NAI PART NO.	DESCRIPTION	RD-503T	RD-504T
C-200209	Ratio Transformer, 3rd, 4th, and 5th Decades	1	
-800941	Knob, GEE-LAR #J-385 or equal	6	6
801877	Switch, polarity		1
405051	Precision Inversion Transformer T-120		

The instrument, as received from the factory, should indicate zero before being turned on. If it does not, reset the meter to read zero by means of the adjusting screw below the bottom of the meter face. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

With the instrument plugged into the proper power source, turn the power toggle switch to "ON." Allow the instrument to warm up about [illegible] minutes for stable operation. For precision measurements, additional time should be allowed for the reference and signal dividers of the PAV to reach equilibrium temperature conditions.

[illegible] CALIBRATION

This calibration is necessary prior to making any measurements. The Complex Voltage Ratiometer contains a passive, wideband, 90° network which permits making this calibration without the need for additional equipment. Behind the front panel door marked "PHASE CALIBRATION CONTROLS" there is a switch and a control. The switch is designated "OPER" and "QUAD CAL." With excitation voltage applied and reference level properly adjusted, the calibration may be performed as follows:

1. Switch to "QUAD CAL" and "QUAD LEVEL" to first position "+".
2. Switch range selector to 1 volt scale and Function Selector to 90°.
3. Adjust the quadrature level control to obtain a null.
4. Switch the Function Selector to 0° and adjust the "QUAD PHASE" control for a null.
5. Switch Range Selector to next most sensitive position.
6. Repeat Steps 3, 4, and 5 until nulls are obtained of less than 0.5 ppm Es or luv (whichever is greater).
7. Switch to "OPER", close door and make measurements.

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[illegible]

1. [illegible] EXC-PAV-CVR switch to the [illegible] position.

2. Follow instructions outlined in the Operation Instruction Manual for [illegible], 500 microvolts type Phase Angle Voltmeter. (Section VII).

3. When using the Phase Angle Voltmeter in this mode of operation, do not connect the ground wire of the PAV to ground of the CVR as this will cause a ground loop.

[illegible] 3-PHASE RATIO

1. 4 Terminal Network: Connect input of test item to EXC OUT terminals of CVR. HI side to red terminal; LO side to black terminal. Using the CVR Test Cable, attach red lead to HI side of test item output and black lead to LO side of test item output.

2. 3 Terminal Network: Connect input of test item to EXC OUT terminals of CVR. HI side to red terminal; LO side to black terminal. Using CVR Test Cable, attach red lead to HI side of test item output. Do not connect black lead to LO side of test item. (Connecting this lead can cause an undesirable ground loop.) See note below.

3. Having connected the test piece as previously described, as well as applying power and excitation, set the EXC-PAV-CVR switch to the EXC position.

4. Set the Range Switch to the appropriate scale (with Function Selector in FUND) and read excitation voltage.

5. Set REFERENCE Switch to the ADJ position and adjust to red line reading on voltmeter. Reset REFERENCE Switch to OPER position.

6. Set EXC-PAV-CVR switch to CVR position.

NOTE: For testing high and low current carrying devices, see Description of Terminals-Connectors Section (EXC OUT).

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. Set the Function Selector to the 0° position.

. Adjust ratio box setting (including polarity switch) to null the in-phase component on the lowest scale possible without illuminating the overload light.

. Set the ratio box so as to [illegible] null by approximately full scale on the Phase Lock Voltmeter. Note this setting and return to the null setting (Step 8).

10. Switch Function Selector to 90° position and vary the ratio box between the null setting (Step 8) and the offset ratio noted in Step 9 above. This variation should not cause a change in quad reading. If a change is observed, adjust the Phase Dial to a position such that no change in voltage is observed while varying the Ratio Box between these two settings. Set the Ratio Box back to the previously determined null position.

~~11. Repeat Step 6.~~

12. Set Function Selector to 90° position and using both fine and coarse controls inject a quadrature voltage to obtain a null reading on the lowest possible scale without illuminating the overload light.

13. Repeat Steps 7, 8 and 12 alternately until both quad and in-phase null levels are less than 1 ppm of the excitation voltage level.

14. The Ratio Box reading indicates precisely the in-phase ratio.

TO MEASURE QUAD

1. Following the steps outlined above under In-Phase Ratio Measurement, set Function Selector to 90°.

2. Turn quadrature coarse switch to CW.

3. Read voltmeter at the most sensitive scale possible.

4. This reading is the quadrature voltage.

TO MEASURE PHASE ANGLES

1. Following Steps 1 through 14 outlined in the procedure to measure in-phase ratio, set the Function Selector to the ∠SET position.

2. Set RADIANS-DEGREES switch to RADIANS position.

3. Set the Angle Scale Set selector to the appropriate position.

   Note: If the in-phase voltage (in-phase ratio x EXC voltage) is greater than 10V, use the HI position of the switch. If the in-phase voltage is less than 10V, use the LO position.

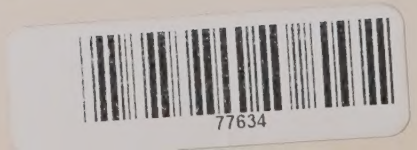
4. Set the Range Selector to the highest decade position (i.e., 10, 1, .1) where a full scale meter deflection can be obtained by adjusting the inner knob of the Angle Scale Set Selector.

5. Without rotating the Range Selector, slide the RAD / DEG. scale on the Range Selector to align the ∠ radians position with the voltage range selected in Step 4.

6. Switch Function Selector to ∠READ. Set Range Switch to the most sensitive scale possible (without disturbing the angle scale to voltage scale relationship).

7. Read the voltmeter directly in angle or radians (depending on setting of Angle Scale Set Switch).

   CAUTION: TO ASSURE ULTIMATE ACCURACY IN INTERPRETATION OF MEASUREMENTS, OCCASIONAL MONITORING OF THE EXCITATION VOLTAGE IS SUGGESTED. THIS MAY BE PERFORMED BY SWITCHING THE EXC-PAV-CVR SWITCH TO THE EXC POSITION.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